No 2695 VOLUME 78 FRIDAY 4 NOVEMBER 1960

FLIGHT

AIRCRAFT, SPACECRAFT, MISSILES

Official Organ of the Royal Aero Club First Aeronautical Weekly in the World Founded 1909

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Iliffe & Sons Ltd, Dorset House, Stamford Street, London SE1; telephone Waterloo 3333. Telegrams Flightpres Sedist London. Annual subscriptions: Home £4 15s. Overseas £5. Canada and USA $15.00. Second Class Mail privileges authorized at New York, NY.

Branch Offices Coventry: 8-10 Corporation Street; telephone Coventry 25210. Birmingham: King Edward House, New Street, 2; telephone Midland 7191. Manchester: 260 Deansgate, 3; telephone Blackfriars 4412 or Deansgate 3595. Glasgow: 62 Buchanan Street, C.1; telephone Central 1265-6.

New York, NY: Thomas Skinner & Co (Publishers) Ltd, 111 Broadway, 6; telephone Digby 9-1197.

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Stark Facts

THE first line of the National Anthem took on a new significance on October 25. Truly by the grace of God the Queen was spared from a disaster which, had it actually occurred, would have appalled the world. But there was no collision, and instead of horror there is anger.

Increasingly the benefits of air transport are attended by the peril of collision. The cause of aviation safety is not promoted by spreading alarm at its dangers, but there is no safety in suppressing or ignoring facts or even in failing to bring them prominently to the public attention. In the belief that the collision hazard, especially between military and civil aircraft, can never be too strongly emphasized we print the following facts on this page:

In the last two-and-a-half years there have been six fatal collisions between civil and military aircraft, at a cost of 191 lives.

More than 1,000 near misses of all kinds are reported each year in both Europe and the U.S.A.

It is four years since the Guild of Air Traffic Controllers urged the need for unified civil and military control. While much has been done in this country to improve liaison and to extend radar coverage, the ultimate ideal of unified civil/military control is still not attained.

The UK has given its blessing to Eurocontrol—the unified upper-air ATC system proposed by the common market countries—but has not yet urged it beyond the draft-convention stage.

We make no comment; these facts in the present context are comment enough.

Kangaroo and Koala

IT is all very well for the Australians to send us Harry Hawker and *Waltzing Matilda,* Jack Brabham and *Tie Me Kangaroo Down, Sport.* What we want them to send us now are orders for some dinkum aeroplanes; and a contribution in this issue from Stanley Brogden suggests that some business might soon be coming up from Down Under.

Mr Brogden, as most of our readers, and all our aircraft builders, are aware, is an Australian who packs a kangaroo punch. But there is nothing savage in his writings. They are, we believe, accepted as fair and objective comment (and if they are not we shall doubtless be hearing otherwise). What is so pleasing about Mr Brogden's contribution is that although the kangaroo has certainly not been tied down, important passages of his article show closer kinship with that gentle creature the koala. "What does encourage a lot of us here," says our contributor, "is the possibility that the new broom in the UK industry may have done such good sweeping as to uncover a new approach to sales."

By the sheerest coincidence, in this same issue Sir George Edwards, executive director, aircraft, of the corporation which has given Mr Brogden particular encouragement by its imaginative sales approach has something to say about Australia, business, and airliners of the more distant future. Sir George remarks that the Australians have always been critical about the apparent reluctance of British businessmen to visit them, and he believes that the reduction in journey time made possible by the supersonic airliner would make countries such as Australia much more accessible and strengthen the links with this country. Because of this he believes that the supersonic airliner will come about.

Into a shivering world a warm new confidence in the British Commonwealth and in its trade and communications seems to be entering.

FROM ALL QUARTERS

R-R to Make Continentals

ON November 1 Rolls-Royce Ltd announced their acquisition of a licence for Continental piston engines, thereby confirming one of the best-known commercial secrets of recent years. The announcement states: "Continental Motors Corp, of Muskegon, Mich, and Rolls-Royce Ltd have signed a licence agreement covering the full range of Continental aircraft piston engines. Rolls-Royce will be able to supply the full range of engines and spare parts and will provide full after-sales service. The licence gives Rolls-Royce exclusive rights for all Continental piston engines and spares in Europe and for Rolls-Royce-built Continental engines in Australia and New Zealand.

"Production facilities will be established by Rolls-Royce for any of the Continental range for which a sufficient market is foreseen, in the assigned territories. Early delivery of Continental-built engines through Rolls-Royce will be possible while production in Britain is being established. British-made parts and engines will be incorporated into the delivery programme as they become available. All parts manufactured by Rolls-Royce will be fully interchangeable with those from the USA."

FILLING A GAP: Announced in this column is a licence agreement between Rolls-Royce Ltd and the Continental Motors Corp whereby the British company will be able to supply a full range of piston engines for small aircraft. Mr J. P. Herriot (left) is managing the venture, news of which was announced by Mr J. D. Pearson (right), chief executive and deputy chairman

The chief executive and deputy chairman of Rolls-Royce, Mr J. D. Pearson, added: "The manufacturing activities associated with the project will be carried out at the Rolls-Royce Crewe factory. The company will establish a network of distributors for these engines. Service, spares and overhaul facilities will also be established in the assigned territories. Mr J. P. Herriot has been appointed general manager of the newly formed Light Aircraft Engine Department." A man of many parts, Mr Herriot joined the company in 1945 as chief development engineer on the early Whittle turbojets. For several years he managed the Rolls-Royce licence department, and since 1958, as an official of the company's International Division, he has carried out a painstaking market survey of light aircraft, with particular reference to their propulsion.

One of the first companies to name Rolls-Royce as a supplier of their Continental engines is BEAGLE—British Executive and General Aviation Ltd—who stated on November 1 that they had "completed arrangements with Rolls-Royce Ltd for the supply to Beagle of the range of the new Rolls-Royce/Continental power-plants . . . which will be installed in the Beagle Executive and Auster/Beagle Aircraft, which are now being developed by the Beagle Co under the direction of Mr Peter Masefield." Previously, Short Bros & Harland Ltd had stated that the SC.7 Skyvan light transport would be powered by "Continental piston engines built in Britain." The engine named for the Skyvan is the IO-520, one of the latest flat-six engines with direct injection, a super-charger and geared drive. Brief details of the Continental range were given in our 1960 Review of World Aero Engines, published on March 18.

HERR VON HERWARTH (extreme right), West German Ambassador to Britain, who visited the Queen's Island works of Short Bros & Harland Ltd on October 26, is seen examining models of the Britannic and Skyvan with Mr David Keith-Lucas (centre), Short's technical director, and Mr J. Dent, chief engineer, guided weapons. The Ambassador also saw the Seacat ship-to-air missile which is to be evaluated for the West German armed forces

The New Air Minister

Under the Government changes announced last week Mr Julian Amery succeeds Mr George Ward as Secretary of State for Air. Mr Amery, who is MP for Preston North, has been Parliamentary Under-Secretary to the Colonial Office since 1958. He served in the RAF from 1940 to 1941, before transferring to the Army. In his new post, Mr Amery becomes a Privy Councillor. Mr Ward, who has been Air Minister since 1957, becomes a viscount. He is leaving political life in order to take up a post in industry

The Queen's Near Miss

UP to the time this issue closed for press, the West German authorities had not traced the Luftwaffe pilots who may have been responsible for the near miss reported on October 25 by the RAF Comet 2 while flying the Queen and Prince Philip home from a visit to Denmark. A review of the incident is on page 698; a leading article appears on page 687.

The Comet 2 was at 35,000ft on airway Red One, about 20 miles north-east of Eelde within the Hanover FIR, when the co-pilot, Flt Lt F. J. Stevens, saw two aircraft on a collision course. He is reported to have said later: "They had damn great Iron Crosses underneath their wings. They turned in as a pair and passed only about 50ft above us. I do not know whether they were taking evasive action. It was a very nasty moment and I was prepared to do something drastic."

Commander of the Comet 2 *Orion* was Sqn Ldr Peter Pullan. On board was Air Cdre Sir Edward Fielden, commander of the Queen's Flight, who said afterwards: "The two aircraft had absolutely no business to be there."

Immediately after the incident an Anglo-German inquiry commission was set up under Gp Capt I. J. Spencer, commanding officer, RAF Benson. He is assisted by Wg Cdr P. Barker of RAF Transport Command, and by three Luftwaffe officers (who spent October 26 at Lyneham): Col H. Hauser, Lt Col C. Cadow and Maj G. Baumann.

In the Commons on October 26 Mr George Ward, Air Minister, said in answer to a question that a draft agreement on Eurocontrol had already been approved in principle.

BAC for Supersonics

IN a written Parliamentary reply on October 27 Mr Peter Thorneycroft, Minister of Aviation, announced that a limited design-study contract is being negotiated with the British Aircraft Corporation. The contract is valued at £350,000 and will obtain for about one year.

"If such an aircraft were to be built," said the Minister, "there

***AIR TOURER:** Orders for 23 Victa Air Tourers, in addition to five of the company's R-2s, are reported on this page. Designed by Henry Millicer, the Tourer is envisaged as a Tiger Moth replacement for the Australian flying clubs*

would be substantial advantages in carrying it out in co-operation with other countries. The British Aircraft Corporation is being asked as part of the contract to explore further with appropriate companies overseas the possibility of collaborating with a view to the sharing of costs and the widening of the market for the product."

The Minister's statement confirmed what has now been popularly believed for some time—that it would be to the Vickers-Armstrongs, English Electric, Bristol and Hunting Aircraft group that money would go for the final preliminary stage in building a supersonic airliner. It might be right to call this the end of the beginning; when the contract has expired and the design study is prepared the Minister of Aviation will then have to decide whether the industry will receive massive financial support to go ahead. No answers were given by Mr Thorneycroft to the questions of size, speed and cost raised in *Flight*, October 21. As far as the British Aircraft Corporation is concerned the maximum number of technicians that can be usefully deployed on supersonic airliner studies are already at work. As a Vickers spokesman put it, "It's a question of just how many hens can sit on one egg."

On pages 690 and 691 are made known the views of Sir George Edwards, executive director, aircraft, British Aircraft Corporation, on the supersonic airliner. He was speaking to the Institute of Directors in London on October 27.

September Overseas Sales

EXPORTS by the British aircraft industry during September totalled £9,904,191. This was some £250,000 more than in the same month last year. The total for the first nine months of 1960 has passed the £100m mark and now stands at £108,283,371, representing an annual rate of about £145m.

The September figure was made up as follows: aircraft and parts, £4,657,024; aero-engines and parts, £4,866,047; electrical equipment, £202,551; aeronautical instruments, £114,179; and tyres, £64,390. India was the leading buyer of aircraft and parts, spending £667,640. The leading aero-engine customer was the United States, spending £1,072,966.

Orders for Victa

SINCE the first firm order for aircraft manufactured by Victa Consolidated Industries of Sydney, Australia—placed one month ago by Auckland Aero Club, New Zealand—the number of Victa aircraft on order has risen to 23 Air Tourers and five R-2s. The two-seat Air Tourer is developed from the Henry Millicer design which won the Royal Aero Club's 1953 competition; and the R-2 is a four-seat, all-metal aircraft powered by a 180 h.p. Lycoming and described in *Flight* of August 12 last.

The Auckland Aero Club order was for six Air Tourers and four R-2s, together worth some £55,750, with delivery at six-week intervals starting in March 1961. The remaining orders include 15 Air Tourers for the Victorian Aero Club, subject to the first production model meeting the specifications; and two Air Tourers for the Latrobe Valley Club.

Victa announced its intention to enter the light-aircraft field with production of the R-2 just over six months ago, and followed this with purchase of the manufacturing rights of the Millicer Air Tourer. Initial tests of the R-2 are expected within the next few weeks, while the already certificated Air Tourer is going into immediate production.

European Space Talks

THE Minister of Aviation, Mr Peter Thorneycroft, discussed space research with French Government officials in Paris last week. His talks were with M. Debré, French prime minister, M. Guillaumat, minister in charge of space research, and M. Messmer, minister for the Armed Forces; and the subject was "the possibility of forming an organization of European countries and of members of the Commonwealth for the development and production of launchers capable of putting heavy satellites into orbit."

A Ministry of Aviation statement added: "The French ministers expressed interest in this suggestion and the questions raised by these ideas are now being studied. It was agreed that the British Government would inform other governments who might be interested of the substance of these conversations."

On his return to London Airport on Saturday, October 29, Mr Thorneycroft said: "I think there is a future for space exploration conducted by Europe and the Commonwealth. There are great advantages in expensive projects of this kind in sharing costs between friends before embarking on it."

IN BRIEF

The Minister of Aviation, Mr Peter Thorneycroft, opened the new applied electronics laboratory of the General Electric Co Ltd at Portsmouth on October 21. This is one of three laboratories operated by the company on behalf of the MoA.

The de Havilland Aircraft Co of South Africa (Pty) Ltd has been renamed Hawker de Havilland (Pty) Ltd and will distribute all Hawker Siddeley Group products in Southern Africa. The board of the new company is Mr Jack Davison, managing director; Mr R. Douglas; Sir Aubrey Burke and Mr F. E. N. St Barbe.

Russia is said to have completed the construction of a 400-ton hovercraft which can travel 1.5 to 2.5m (5ft to 8ft) above the water at a speed of 170 to 200km/hr (105 to 124 m.p.h.). A proportion of the cushion-air supply provides forward propulsion. The hovercraft can also travel over land.

Viscount Caldecote, executive director, guided weapons, British Aircraft Corporation, is to lecture at the Institution of Electrical Engineers, Savoy Place, London WC2, next Friday (November 11) at 5.30 p.m. on *The Future of "Electrics" and Electronics in Aircraft and Guided Missiles*. This is an inaugural meeting to institute a common forum between the Institution and the RAeS on the applications of electricity in aircraft.

Details of a £100,000 SHAPE contract for air transportable HF radio stations have been given by Racal Engineering Ltd. The stations, designed for instant and precise alignment to any frequency, are completely self-contained. Alignment is made possible by the new Racal MA.150 channelizer unit, which operates in 1kc steps, permitting an accuracy of frequency setting to within one part in 10^8 both for the transmitter and the receiver.

The Guild of Air Pilots and Air Navigators is having a busy afternoon and evening in London on Thursday, November 17. It will begin with the test pilots' a.g.m. and the professional-licence holders' meeting, both at 2.45 p.m. on board H.Q.S. *Wellington*; then will come the Guild's annual service, at 5 p.m. at St Michael's, Cornhill; and this will be followed by the Guild's a.g.m. at 6.45 p.m. on board *Wellington*, terminating with a buffet supper.

A verdict of accidental death was returned at the inquest at Dunstable last week on John Westhorpe, an instructor of London Gliding Club, and Peter Carter, a pupil pilot, who were killed on September 30 when the T-21b glider in which they were flying dived into the ground after launch from the club site at Dunstable Downs. It was stated at the inquest that Mr Westhorpe was suffering from epilepsy and acute tuberculosis at the time of the accident. The jury recommended that the facts should be brought to the attention of the Ministry of Aviation in an effort to prevent similar fatalities.

A free 132-page book of motoring information, *The Autocar Motorists' Companion*, is being offered by our associated journal *The Autocar*. It will be given away in four 32-page sections, the first with today's (November 4) issue and the others with those of November 11, 18 and 25.

***FIRST FLIGHT** of the Boeing-Vertol 107 twin-turbine helicopter, capable of cruising at speeds in excess of 155 m.p.h. The 107 is the subject of a news paragraph on page 696*

National and International Aspects

THE following abstract of an address to the annual conference of the Institute of Directors at the Royal Festival Hall, London, on October 27, contains the concentrated sagacity of one of aviation's most respected personalities—Sir George Edwards, CBE, BSc, HonFRAeS, HonFIAS, executive director, aircraft, British Aircraft Corporation Ltd, and managing director, Vickers-Armstrongs (Aircraft) Ltd. The address is necessarily printed here from Sir George's draft and may not conform precisely with his spoken words. Among Sir George's audience were many of the nation's industrial leaders, and the immense issues now confronting the aircraft industry could not have been expounded to them by a more competent authority.

OPENING his address, Sir George Edwards said that he could see several reasons why the subject should be important to his audience. There was the value of aviation to the nation in defence, in the provision of equipment to the British airlines, and as a branch of export; there was also the enduring value to other industries of developments pioneered especially for aviation, such as radar. But he was sure, too, that most of his audience were personally interested in aviation as the means of world-wide travel in the joyful pursuit of exports. Aviation was a substantial business in this country, as indeed it was all over the world. In the United States, for example, the aviation and allied industries had for years been the biggest industrial employer of labour. It was unfortunate that, at times, aviation over here had been associated with too much glamour and excitement. The industry had its own share of the blame to carry in that respect. Too often, a worthwhile job with clearly defined limited objectives had been heralded as the saviour of mankind when, in the end, it merely did what it was supposed to do; and, because the quite unjustified early claims could not be met, discredit fell on the people concerned and the industry as a whole.

"The ambition of most of us who have spent a large part of our working lives in British aviation," continued Sir George, "is to see it credited with a greater sense of responsibility and an awareness that here is a solid and matured industry of great and lasting value to the nation.

"No one should be under any illusions about the role of the industry in another war, or—let us be more optimistic—in the deterrent to prevent one. All the guts and courage of the British fighting man will be of no avail unless he has been provided with weapons that can match the enemy's, and let there be no doubt that the principal weapons upon which he and the nation will have to rely will be those forged by the skill and craftsmanship of the people in the aircraft industry. I wonder what degree of freedom we should be enjoying today if, twenty years ago, Mitchell's Spitfire and Camm's Hurricane had not been ready at the right time."

But in purely commercial pursuits, quite apart from our contribution to the deterrent, we had a job to do. We were doing our best to put British airlines into a competitive position in which they were able to beat the other airlines of the world. We had an export performance which could be summed up by saying that over the last five years we had sold overseas an average of about £120 million sterling in each year.

We were continually being told that we were in a very difficult balance-of-payments situation. It seemed to the speaker that the most powerful form of export to correct such a situation was one which combined the minimum import content with the maximum of native ingenuity and man-hours. An aircraft produced about 300 shillingsworth of export for one pound of its empty weight; a motor car produced about ten shillings-worth of export for one pound of its empty weight. As a means of improving the balance-of-payments situation, therefore, the aircraft industry (which incorporated aero-engines, of course) was extremely attractive by virtue of its high exchange-rate. This, added Sir George, was no way intended to be a reflection on the value of motor cars or any other exports.

"Although 'prestige' is a much overworked word," Sir George went on, "I believe that a great deal has come to Britain by virtue of the use of the industry's products in over 160 different countries and territories. Clearly the Government took all this into account when they recently decided to assist new British civil aircraft projects. That we needed such assistance could be demonstrated by those of us over here who have attempted to tackle big new civil aircraft as 100 per cent private ventures. One of our main reasons for doing this was that it gave us a measure of stability not present in the Government defence contracts which include a break clause."

Recent company reports from the United States had shown the need for Government help even more clearly. The leading American aircraft companies were blessed with Government contracts far greater than anything we see and most of them had a civil aircraft turnover which is little more than 20 per cent of their total; but with all these advantages they had been having a very painful time. The great Boeing company; Douglas (the greatest name in civil aviation); General Dynamics, who only had an interest in aircraft through two subsidiary companies; and Lockheed—all these had shown heavy losses on their civil aircraft currently in production. It was a sobering thought that between them these four big companies had written off over £200 millions on their current civil aeroplanes, and three of this Big Four had declared net losses on their 1960 operations to date. That they were able to write-off this enormous sum and still stay in business was, of course, only made possible by their massive Government programmes. It was, therefore, not surprising that the British aircraft industry should need some Government support.

Credits and Exports

Sir George continued: "In view of past criticism of Government feather-bedding of the aircraft industry, I should like to point out that these new contributions are so arranged that the Government and the manufacturer will recover the whole of theirs before the latter makes anything like a worthwhile profit on the operation. The Government will then continue to exact a levy which in the end could very well make a handsome profit out of their side of the deal—and it would not be the first time they had done that.

"The industry in its turn has submerged the traditions and loyalties and enthusiasms of single companies into those of the big new groups. Many of us have been advocating this policy for years and the industry is much the stronger for it. In order that Government and industry can fully exploit this new arrangement one thing that will be needed is a more far-sighted approach to the whole problem of credit. To many of us, the Export Credits Department has seemed to be trying to ride two horses which were not always running in the same direction. On one it tried to operate as a commercial profit-making insurance company, on the other it was acting as the handmaiden of Government policy in the drive for exports. I have no doubt as to its proper function—to prime the pump for exports. And it cannot fully perform this function if it adopts an over-cautious and unrealistic attitude to what is described as the 'credit race.' It is encouraging to see that the President of the Board of Trade shows a swifter recognition of the credit terms being offered by our competitors, so that in certain limiting circumstances we can now offer seven years' credit and other concessions. This is a move in the right direction and I am sure that the President of the Board of Trade will see that his department offers us these revised terms with a rapidity that will match the rate at which its transatlantic counterparts have passed on their terms to our competitors."

There had recently been a movement towards a more intense examination of a military requirement before it developed into a large-scale development programme. The speaker hoped that this really would mean that jobs were not started until everybody was pretty well convinced that they were going to come to fruition. The industry desperately needed in its programme a stability which starting and stopping could never bring.

". . . with our new family of rear-engined civil jet aircraft we are particularly well placed to take a big share of the new round of buying which the airlines of the world will soon be embarking upon."
Depicted is the BAC Super VC10

of the Aircraft Business

AN ADDRESS BY SIR GEORGE EDWARDS

The export figures he had quoted were largely the backlog of Britain's old successes both in the civil and military fields. He was confident that, with our new family of rear-engined civil jet aircraft, we were particularly well placed to take a big share of the new round of buying which the airlines of the world would soon be embarking upon. Provided, therefore, that the Government continued its policy of supporting the industry he felt confident of our future.

"The American aircraft industry will have to go through mergers similar to those through which we have just passed," said Sir George. "They generally do things two or three years after we do. As I have indicated, they are pretty unhappy with their civil financial operations. I think this could well be the moment to pause and, because our position is so much stronger by virtue of our regrouping, perhaps decide that now is the time to try to come to some arrangement with our competitors. Perhaps too much pursuit of exports in Canadian winters and New York summers is making me a little weary; but I could extract a lot of pleasure from selling aeroplanes in company with the Americans if, at the same time, I was getting the benefit of the credit terms which the Export & Import Bank have consistently offered, instead of having them in opposition. What I am saying might be interpreted as a vote of no confidence in our own ability to go it alone; but it is nothing of the sort. I think you will agree that the time to negotiate an international arrangement with the Americans is when one is negotiating from a position of strength, as I believe we now could be. There is a lot to be said for injecting some sanity into the whole way in which the international aircraft manufacturing business is conducted. If the airlines, who have bought their new aircraft too cheaply, were making a profit as a result, it might not be so bad; but as things stand at the moment nobody is."

Quite soon we in Britain would be starting work on a supersonic transport. It might be asked why, as the present jets would get one across the Atlantic in five-and-a-half hours, anyone would want to do it in two. The answer was that there were lots of places to which one could not go in five-and-a-half hours. He believed that the ability to get the journey time between any two places down to twelve hours or less had always been the starting point of a great increase in travel and trade between those two places. A supersonic transport would get one to Australia in ten hours; in the same way that the jets had enabled people to visit the United States for a matter of a day or two in order to discuss some important business personally, so the supersonic aircraft would enable the same thing to be done with Australia. The Australians had always been critical about the apparent reluctance of British businessmen to visit them in person. The reduction in journey time made possible by the supersonic jet would make countries such as Australia much more accessible and strengthen the links with this country. Because of this, he believed that the supersonic airliner would come about; that, if it was handled in a responsible and sensible manner, it could be of great service to man; and, in particular, that it would be of service to those who would be the first users.

Two Basic Questions

"There are two basic issues to be settled: one is 'how fast?' and the other is 'how soon?' The speed issue is quite simple; you have the choice of going at just over twice the speed of sound or at three times the speed of sound—1,500 m.p.h. or 2,000 m.p.h. The lower speed enables us to use the light alloys and structures similar to those employed in today's aeroplanes; the higher speed will mean that we have to use steel or titanium because the light alloys will melt.

"Your present jet crosses the Atlantic at something over 500 m.p.h. and we are, therefore, talking about the choice, in the new aeroplane, of three or four times the present speed: you now take five-and-a-half hours to get to New York—the 1,500 m.p.h. one will take three hours and the 2,000 m.p.h. model will take two-and-a-half; London - Sydney will take ten hours on the 1,500 m.p.h. touch and eight hours on the fast one. Well, which shall it be? By virtue of a lot of concentrated work on this problem the British just about know how to do the slower one and, I think, have every intention of doing it. The Americans could undoubtedly find out how to do it. Neither of us knows how to do the 2,000 m.p.h. one—and do not be misled by anyone who says he does.

"I have grave doubts whether the airlines would be able to absorb anything more than the 1,500 m.p.h. aeroplane; their previous biggest jump has been from 350 to 500 m.p.h. In short, I can see no sense in doing anything other than the 1,500 m.p.h. one and I doubt very much if that will be safe enough to carry passengers before the 1970s. I am quite certain that the airlines will not be able to afford it before then. They have to depreciate the equipment already in their possession, and that will take the whole of the 1960s. In the past, lack of finance has not stopped the airlines indulging in a rat-race; one of them is lured on by a wicked designer into a premature purchase; this gets it going, and another designer is bullied by another airline to do a bit better a bit sooner. So off they all go and without much doubt everybody goes bankrupt—especially the manufacturers. You might well ask what has all this to do with you; that this should be a lecture to the Royal Aeronautical Society, not to the Institute of Directors. But it is to do with you because, in the early stages, the purpose of the supersonic transport will be to carry business people. As I have already said, I see a big expansion of travel to such places as Australia. The backbone of air travel—for example, the 87 per cent who are carried across the Atlantic on economy-class fares—will not be going in a supersonic transport in the 1970s; they will continue to go in the subsonic ones. It will, therefore, be this audience which will over the initial period provide the customers for this aircraft.

Cooking Hints

"The thing that worries me is that somebody, on your behalf, will decide that you shall be conveyed in the 1970s in the 2,000 m.p.h. aeroplane. Take my advice and don't fall for it. If you say that you are not going to buy a ticket on anything faster than 1,500 m.p.h. for the next twenty years you will be acting in the best interest of the airlines, the aeroplane manufacturing industry and your own physical well-being. You probably say already that you have been cooked when you get out of an aeroplane which has a faulty air-conditioning system; you wait until the air-conditioning system fails on your supersonic transport—you really *will* be cooked."

Sir George concluded by saying that the development cost of the supersonic transport would lie between £50 million and £100 million. He still felt that it was absolutely right that we should go ahead. It was our job to better communications and bring the farthest parts of the world closer together. It was also our job to see that it was done in an orderly fashion—and 2,000 m.p.h. was disorderly.

"When I was in the United States I put to a fairly big audience the general proposition that in the broad sense both the supersonic transport and international collaboration were good things. They were not unsympathetic. The inevitable reaction which one gets over there, of course, is 'What are the Russians going to do?' The inference is that if the Russians decide to produce a supersonic transport the Americans will have to do something better and sooner. This terrifies me, because if the Russians decided that they wanted to make an all-out attack on the economy and substance of the airlines and aircraft manufacturing industries of the West, then easily the cheapest way in which they could really bring chaos to both would be to produce a so-called supersonic transport flying at an alleged 2,000 m.p.h. If we fell for this one, and got ourselves into what I might describe as a Sputnik panic, then I think we should deserve everything that happened to us. I should certainly stop wasting my breath on advocating any sanity in the business."

Air Marshal Hugh Campbell, CAS of the RCAF (left), and Mr George Pearkes, Canadian Defence Minister, leaving the first Grumman Albatross which the RCAF has acquired for ASR operations after its inaugural flight at Rockcliffe, Ont. Ten are to go into service

SERVICE AVIATION

Air Force, Naval and Army Flying News

New Carrier Types?

DURING his speech at the Trafalgar Day luncheon of the Navy League the First Lord of the Admiralty, Lord Carrington, dropped a hint that the Navy was considering a new type of aircraft carrier. "We are at the moment discussing the problem of a new generation of aircraft carriers," he said, adding, "and perhaps even more important, the aircraft which will go into them—because on the aircraft would depend the size and the shape of the ship."

Cyprus Defence Exercise

IN last week's autumn air defence exercise for Cyprus—Exercise "Jessie," held from October 26 to 28—units from Fighter Command, Bomber Command, RAF Germany and British Forces Arabian Peninsula participated in addition to MEAF squadrons. Two Hunter squadrons (Nos 54 and 65) and a Mk 9 Javelin squadron (No 25) were based at Nicosia and a Hunter squadron from Aden (No 8) operated from Akrotiri. Also operating from Akrotiri were Canberras of the MEAF Light Bomber Wing and from No 213 Sqn (RAF Germany), and Valiants from No 18 Sqn, Bomber Command. Canberras from the Malta-based No 39 Sqn also took part.

KL Handed Over

RAF installations at Kuala Lumpur airfield, focal point for aerial operations against Malayan Communist terrorists since 1948, were formally handed over to the Royal Malayan Air Force on October 25. Transfer of the base as a gift from Britain was made by the High Commissioner, Sir Geofroy Tory, to the Malayan deputy Prime Minister and Minister of Defence, Tun Abdul Razak. Present at the ceremony were the FEAF Commander-in-Chief, Air Marshal A. D. Selway, and the AOC No 224 Group, AVM R. A. R. Rae.

In the 12 years since the RAF started to use the civil airfield at Kuala Lumpur as a base for Operation Firedog—British Commonwealth support for ground forces fighting Communist terrorism—375,000 sorties have been flown in 36 different types of aircraft. The first strike was made in July 1948 by a Spitfire of No 28 Sqn, and the last squadron operating from there has been No 52 (Valettas), which will continue to drop supplies from Butterworth to forces engaged against terrorists on the Siamese border. Other RAF units at KL have been moved to Butterworth or to Singapore.

Congo Airlift

HASTINGS aircraft of RAF Transport Command have been carrying out a regular airlift of reinforcements and supplies to the Ghanaian infantry brigade forming part of the UN security force in the Congo. Since the flights began on August 1, the RAF have flown about 2,000 troops and nearly 100,000lb of freight and over 8,000lb of mail from Accra to Leopoldville. The airlift is carried out by relay detachments of two Hastings. The current operators are from No 114 Sqn, based at Colerne, Wilts, and commanded by Wg Cdr L. V. Craxton.

Smoke of Battle

A WHIFF of the smoke of Whitehall battles between the Air Ministry and the Treasury drifted through the officers' mess at RAF Newton on Tuesday of last week when the VCAS, Air Marshal Sir Edmund Hudleston, referred in his speech at the Nottingham UAS annual dinner to the fight being waged to keep the university air squadrons in being. The Air Council, he said, had always considered that they should continue; the Treasury had "trained a microscope" on to them and further pressure was to be expected.

Sir Edmund said that the Air Council had always "looked at the intangibles" in considering the squadrons, such as air-mindedness in national leaders who had passed through them; they had never been regarded as a form of recruitment. But if the Treasury asked "What are you getting out of it?" the argument that seven officers from Nottingham UAS were spending some time in the RAF was a much stronger one to put to them.

He paid tribute to the universities for their support, and this was reciprocated by the Principal of Loughborough College, Dr H. L. Haslegrave. His view was that of a civilian who had seen RAF Newton built some 25 years ago and remembered that in its wartime days "men had gone out from there to face hazards." He was grateful to the RAF not only for its part in ensuring peace but also for the help given to the college and Nottingham University.

Both these institutions supply members to the air squadron and its commanding officer, Sqn Ldr H. S. Horth, spoke of the satisfactory state of recruitment.

Air Marshal Sir Douglas Jackman, AOC-in-C Maintenance Command, laying the foundation stone on Wednesday of last week of the Command's new headquarters building at RAF Andover

Autumn leaves whirling around the Fairey Rotodyne as it participated in the RAMC demonstration Exercise "White Swan" at RAF Odiham last Friday. It has just deposited a "helipod" (lower left) containing two operating theatres. Comet, Britannia and Beverley aircraft of Transport Command also participated in the exercise, designed to assess new forms of bringing medical aid to battle casualties and removing them to hospital. Some 180 senior medical officers of the Navy, Army and RAF, and Commonwealth and foreign Services attended the demonstration

Missiles and Spaceflight

SUPPORT FOR PRIVATE SATELLITES

The viewpoint of the National Aeronautics and Space Administration on suggestions that private industry should launch communications satellites was indicated by the Administrator, Dr T. Keith Glennan, in a speech at Portland, Oregon, last month. The one firm proposal of this nature so far (reported in last week's issue of *Flight*) was that made by American Telephone and Telegraph Co, described by *Fortune* as the world's largest private enterprise.

"NASA's support will be given to technically promising private proposals," Dr Glennan said, "on a cost-reimbursable basis. This means that NASA will, to the extent of its statutory authority, make vehicles, launching and tracking facilities and technical services available at cost to private companies, provided the private plans for the development and commercial utilization of communication satellites are technically promising and in general consonance with the requirements of other licensing bodies."

Dr Glennan also disclosed that NASA's own plans in the field of communications satellites were being accelerated. "While continuing with its development programme using the passive reflector type communications satellite of which the Echo balloon is the first experiment, NASA is programming an early demonstration of the technical feasibility of very lightweight active-repeater satellites placed in an orbit 3,000 to 5,600 miles above the surface of the Earth. NASA will explore with the aid of industrial contractors the main technological approaches which do not duplicate private industrial developments which are aimed at commercial operations."

AFTER MERCURY

Contracts for feasibility studies for the Apollo three-man spacecraft, as part of the manned spaceflight programme which the US National Aeronautics and Space Administration is planning as a follow-on from Project Mercury, are expected to be announced within the next two weeks. The objectives of the studies will be (1) to define a manned spacecraft system which meets the mission requirements; (2) formulate a programme plan for implementation; (3) identify areas requiring long-lead-time research and development effort; and (4) analyse the cost of providing the system.

The Apollo missions will include Earth orbits, circumlunar flights and lunar orbits. Present NASA planning is based on industry and NASA research and design studies continuing until mid-1961; vehicle design, research and development and prototype flights from 1961 to the end of 1965; and Earth orbital and circumlunar flights from 1966 on.

The companies which have put forward Apollo proposals are Boeing, Chance Vought, Convair, Cornell Aeronautical Laboratory, Douglas, General Electric, Goodyear Aircraft, Grumman, Guardite Space Technology Division of American-Marietta Co, Lockheed, Martin, McDonnell, North American and Republic.

MONEY FOR SPACE

Contracts placed by the US National Aeronautics and Space Administration during the first six months of this year totalled over $134 million. Individual contracts included the following:—

Thompson Ramo Wooldridge Inc, Tapco Group (Cleveland, Ohio), $4,300,000 for the development of Sunflower solar auxiliary power system;

Grand Central Rocket Co (Redlands, California), $423,294 to design, develop, fabricate and make the necessary tests to demonstrate the feasibility of "a unique rocket" and to develop a prototype version;

Western Electric Company Inc (New York City), $33,058,690, worldwide tracking system for Project Mercury;

Douglas Aircraft Company Inc (Santa Monica), $68,838,160 for services and material to provide for the design, development, fabrication and test of ten Saturn S-4 stage vehicles.

JOINT AMERICAN-ITALIAN ROCKET PROGRAMME

Italy and the United States are to co-operate in a series of sounding-rocket firings to obtain scientific data on the upper atmosphere. A number of small sounding rockets and ground optical instrumentation are to be provided by Italy, while the National Aeronautics and Space Administration will supply the payloads together with technical guidance on launch aspects.

Firings will take place from Sardinia, and the scientific data produced will be analysed by the Italians. Experiments include a study of wind shear at heights of 120-140 miles; temperatures; densities; and spectrographic work.

Intense heat, noise and de-pressurization are simultaneously applied to the unfortunate test subject in this test chamber at Boeing's space medicine section. One company study involves the anticipated physiological stresses on pilots of the forthcoming Dyna-Soar vehicle, in which programme the company is handling vehicle manufacture; integration of vehicle and booster; and assembly and testing

EXPERIMENTS FOR ORBITING OBSERVATORY

Among the experiments planned for NASA's orbiting astronomical observatory (OAO), the Grumman contract for which was reported in a recent issue, are those proposed by three universities, the Smithsonian Astrophysical Observatory and the Goddard Space Flight Center. Details of these proposals are as follows:—

Smithsonian. Several eight-inch telescopes, each coupled with a video tube to map ultra-violet radiation over the entire sky, in order to study hydrogen content of space and investigate how stars are formed.

University of Wisconsin. To measure brightness of ultra-violet emission from the stars, leading to information on temperatures and structures of stars and their life-histories.

Goddard Space Flight Center. To use a 36in mirror and spectrometer to study emissions from a wide range of celestial bodies. This experiment is designed to investigate further areas which sounding rockets have shown to be particularly bright with ultra-violet radiation.

Princeton University. To use a 24in mirror and spectrometer to study cosmic gas and dust by observing them against the stars. The spectrometer can determine the effect of cosmic gas and dust on the radiation from a star, and the experiment should indicate whether the elements occur in the same relative proportion everywhere in space.

Harvard University. To make spectrographic studies of solar activities to improve the understanding of Sun-Earth relationships.

BMEWS ADDITION

An RCA tracking radar is being installed at the Ballistic Missile Early Warning site at Thule, Greenland, to complement the existing GE detection radars. Provision for three of the tracking radars was made in the original construction of the Thule site, and the radome and pedestal parts of the one now authorized have already been delivered.

The new radar at Thule is similar to the three which are to be installed at Fylingdales Moor, Yorkshire. A description of the equipment was included in a report of a visit to RCA at Moorestown, New Jersey, in *Flight* of October 21.

Total cost of the five main BMEWS installations—forward sites at Thule; Clear (Alaska) and Fylingdales; and Zone of the Interior control centres at Colorado Springs and Omaha—was originally estimated at $952 million, of which $500m was for Thule.

Since BEA started operations one out of every three passengers has been carried by DC-3s. Last Monday, October 31, the last scheduled Pionair mainline service was operated between London and Birmingham by this 23,000hr veteran's sister-ship, G-AGZB, flown by Capt P. R. Griffin, acting flight manager Pionairs. Unhappily, in foggy weather at Elmdon, the aircraft overshot the runway and came to rest in soft ground beyond the boundary fence. There were no injuries, except to the sense of occasion, and Pionairs will continue to represent BEA on the Scottish Islands routes and on cargo work

AIR COMMERCE

BEA's CURE-ALL

THE signing of a pool agreement with Aeroflot means that BEA now shares earnings with all of its 17 European "competitors." In the case of the Olympic Airways and TAP pools, costs as well as earnings—i.e., profits—are actually shared. No details of the pool with Aeroflot can be disclosed.

Since the pools with Air France and Swissair were signed at the beginning of 1959, Aeroflot have been BEA's only competitor in the true commercial sense. At present both BEA and Aeroflot run two return services weekly between London and Moscow (with Comet 4Bs and Tu-104s). When the pool agreement comes into force on May 1 next both airlines will increase their schedules to three return flights weekly. BEA's bookings on this route for next year, when there is to be a British Fair in Moscow (from May 19 to June 4), already approach 2,000.

Flashback: "Although pooling, in some cases, has the advantage of rationalizing frequencies and capacities, I hope no one will get the idea that it is the cure-all for all routes. It certainly is not that—there are undoubtedly routes on which straight all-out competition is the right commercial course. Every route must be judged on its merits." —Lord Douglas, chairman of BEA, December 1957.

4d A MILE TO BERMUDA

ANOTHER reduction in London - Bermuda Britannia fares is announced by BOAC and its pool partner Cunard Eagle, following the recent "Skycoach" fare cut from £153 to £130. Now *this* fare is cut to £114 6s, though as a special rate for 17-day excursions only.

This is cheaper than the old "VLF" proposal (£124) and, significantly, it is exactly the same as IATA's cheap 17-day winter excursion by propeller airliner from London to New York. It seems that, far from British Skycoach fares undermining the IATA rate, the reverse had looked like happening on this route.

The new Bermuda fare is equivalent to little more than 4d a mile for the round trip. At the same time the standard economy-class return fare comes down from £180 to £154 7s—again bringing the fare level more into line with the London - New York IATA rate. Comparable reductions are offered to Nassau also, and thence (by Cunard Eagle only) to Miami.

TEAL's last flying-boat service was operated recently between Fiji and Tahiti by the company's last Short Solent, which is now retired. The pilot was Capt J. Shepherd

SPRINGBOK BOEING ACCIDENT

ONLY a month after starting scheduled services between London and Johannesburg one of South African Airways' three Boeing 707s was badly damaged after over-running during an emergency landing at Nairobi Airport on October 30. None of the 79 passengers and 12 crew on board was hurt.

The 707 was *en route* from Johannesburg to London via Salisbury, Nairobi, Rome and Frankfurt. According to a passenger, Mr K. Roseveare: "I felt an enormous bump as though we had made a very bad landing. But as soon as I looked out of the window I saw we were up in the clouds." Another passenger added: "The pilot put on full throttle and we climbed at a steep angle. The plane began to fill with fumes—I suppose they were from hydraulic fluid—and people's eyes began to stream and there was a lot of coughing. After an hour or fifty minutes the pilot said that he was going to make a belly landing."

This is the third Boeing 707 to be damaged on landing in the past month. The first, an Air France aircraft, landed short at Pointe à Pitre, Guadeloupe, on October 7. It lost its starboard undercarriage and was badly damaged in a long skid. The other aircraft involved was an American Airlines 707 which made an emergency landing at Carswell Air Force Base, Fort Worth, Texas, on October 25, when its nosewheel failed to lower. Damage in this case was comparatively slight. There were 126 people on board but none was injured.

CUBAN TAKEOVER BID

YET another Cuban airliner was hi-jacked last week. The airline involved was Aerovias Q of Havana. According to reports from Key West, Florida, an armed man, believed to be the copilot, on October 29 forced the pilot to fly to Key West after shots had been exchanged. A guard, apparently in charge of political prisoners, was shot dead, the pilot was shot in the arm and the copilot was wounded in the head. A boy of 14 was also wounded.

The aircraft had taken off from the military airport at Havana and was flying to the Isle of Pines.

Footnote: A Cubana DC-3 was seized in flight by rebels on October 21, 1958. A Cubana Viscount crashed off Cuba on November 1, 1958, as a result of armed intervention. A Cubana DC-3 was seized by rebels in flight a few days later.

GASHOLDER LANDING SYSTEM

"IT was an honest-to-goodness mistake—nothing more and nothing less. I was on the radar approach through four-fifths cloud to land on London Airport's main runway. I was told to come straight in as soon as I was in line with the gasholder on the runway's approach.

"Unfortunately there's a gasholder directly in line with Northolt's main runway—and that's exactly parallel to London Airport. It wasn't until we actually touched down I realized something was amiss.

"I had to brake pretty hard, but if necessary we can make a reasonable landing in the distance we had.

"I've been to London Airport scores of times. I can't imagine how this happened. But it's one of those once-in-a-lifetime mistakes that anyone can make. I'm only glad to say that we came out of it O.K. But it was a most embarrassing situation."

It was in these terms that Capt Warren Beall, pilot of a PanAm Boeing 707 on a flight from Istanbul to New York via Frankfurt and London, last week explained his headline-catching unscheduled landing on Northolt's 5,400ft runway. He stopped safely, although with only 100yd to spare, and his 41 passengers were transferred to London Airport by coach. Two hours later Capt Beall flew the empty Boeing out of Northolt with a comfortable margin. Pending a PanAm inquiry, he subsequently returned to the US as a passenger in the same aircraft.

Normal radar approach procedure from Watford or Epsom ranges is to follow a standard track, adjusted as necessary by London Director, who vectors the aircraft on to the final approach path. The final approach aid is either precision-approach radar or, as in this case where there was bright sunshine beneath the clouds, visually. There is no ILS on 23L, but the approach track of 230° can be checked by the NDB NE 334 2½ miles from the runway. Apparently misled by flying into the sun, Capt Beall mistook the gasholder at South Harrow, in line with the 08/26 runway at Northolt, for the Southall gasholder 3.3 n.m. northeast of London Airport. Both are about the same size and colour, but the Southall gasholder is the highest local obstruction listed for London Airport by more than 100ft. Collectors of trivia may care to know that when it was built in 1936 it was the second largest gasholder in the British Empire.

Taxying in at Wisley one day last week at the end of its 55th "engine assurance" flight is Vanguard G-APED. The commander, Bill Aston of Vickers, is in the copilot's seat; in the left seat for this particular three-hour flight was Mr M. G. Howett, ARB, and in the jump seat Capt W. J. Wakelin, BEA. See story below

"Flight" photograph

THE VANGUARD'S TEN-HOUR DAYS

AT Vickers' flight test base at Wisley last Monday, two Rolls-Royce Tyne engines, an inner and an outer, were removed from Vanguard G-APED, the aircraft which since October 6 has been engaged in an intensive programme of 10hr/day "engine assurance" trials. Having each flown 200 hours, these two fully modified engines were exchanged for two new modified Tynes and despatched to Rolls-Royce at Derby for stripping and ARB inspection.

Meanwhile G-APED is continuing the programme for a further 50 hours so that—perhaps as this issue appears—the other pair of Tynes can be pulled out for a 250-hour strip and inspection. The aim is to have the Tyne proved and fully certificated so that BEA and TCA can sign for their first aircraft, respectively V.951 G-APEE and V.952 CF-TKD, before the end of the month. The Tyne assurance programme has also been shared by the Rolls-Royce-operated Tyne Ambassador.

The V.951 (BEA) airframe has been virtually certificated since June, when the failure of a Tyne compressor wheel—eventually traced to heat-treatment technique—occurred on the test bed. At Rolls' request about 40 Tynes were returned to them for remanufacture and other changes, including a modification to the tail bearing.

Vanguard flying has continued in a limited way during the summer with G-AOYW, Vickers' own aircraft, and CF-TKA, the first of the TCA fleet. These two aircraft have been fitted with a set of engines life-limited (though not operationally limited) to 150 hours or 700 starts. Total Vanguard flying time to date with 11 aircraft is 1,750 hours.

The trials now nearing completion have meant some hard work for Vickers flight test department. Two hundred hours have been flown with one aircraft in twenty-one days (no Sunday flying is permitted at Wisley), an average of nearly ten hours per day, the record daily utilization being nearly 11½hr. Usually there have been three daily flights around the British Isles, each typical of BEA stage lengths and procedures, and with senior corporation pilots participating (usually two per flight, ten in all being assigned to the programme). The weather has been unco-operative: one particular five-hour flight was made in cloud from soon after take-off until breaking cloud at 400ft at Wisley on the final approach.

BEA's Vanguards will probably carry their first passengers on the London - Paris route over the Christmas holidays, helping out Viscounts on an *ad hoc* basis during the rush. The first full Vanguard schedules, London - Paris, do not begin until March 1. On April 1 the domestic trunk to Glasgow will be operated by Vanguards; the routes to Edinburgh and Belfast internally, and the international routes to Madrid, Malta and possibly Warsaw, will be progressively taken over by Vanguards during the summer.

LAW ON THE SIDE OF NOISE ABATEMENT?

THE Port of New York Authority are seeking a noise-abatement injunction against Delta Air Lines in the US Supreme Court. This is the first time that PNYA have adopted legal action to enforce its noise restriction rules at Idlewild. It is alleged that Delta have "repeatedly planned and conducted its jet flights" in disregard of regulations limiting night flights and placing specific limits on noise over populated areas.

Legal action, it seems, is being taken *pour encourager les autres*. A careful check on compliance is kept for every jet take-off and landing at Idlewild. According to PNYA figures Delta violated the rules on 26.2 per cent of its take-offs between January and September and in the last month of the period violations rose to 36.4 per cent of all take-offs.

TWO FATAL US ACCIDENTS

ACCIDENTS in the US last week to a DC-4 and a C-46 resulted in 34 people losing their lives. The DC-4, which belonged to Northwest, crashed in Montana on October 28.

It is reported to have flown into the side of a mountain 20 miles west of Missoula, where it was due to land after a flight from Spokane, Washington. All twelve on board were killed.

The C-46 had been chartered from Arctic-Pacific Inc to take home members of the California State Polytechnic football team and their supporters after a match near Toledo on October 30. The aircraft took off from Toledo municipal airport in heavy fog but crashed shortly after leaving the ground. Of the 48 people on board 20 passengers and two of the crew were killed. The FAA has revoked the airline's operating certificate.

Lined up below are four of the latest-type transports from Boeing—720s for American Airlines. They are part of a batch of 18 which will be delivered between now and mid-1961, supplementing seven already in service with that airline. Another Boeing 720 is the subject of the picture on the right. Sampling the cockpit with Fred W. Spofforth, a Boeing pilot, is HE Dejazmatch Mengeshia Seyoum, chairman and president of Ethiopian Airlines, which has on order two Boeing 720Bs

AIR COMMERCE . . .

Here is another in-the-air photograph of Russia's new feederliner DC-3 replacement, first performance details of which were published in "Flight" on July 22. Some notes on its construction are given in the accompanying paragraph. (Below) Interior of the An-24 shows a nice line in striped seat-covers, substantial luggage racks and central fluorescent lighting. The lighting makes an interesting comparison with that suggested for the Trident (see photograph below)

RUSSIA'S DC-3 REPLACEMENT

AS a sequel to the first full description of the Ilyushin Il-18 (*Flight*, July 1, 1960), some official details can now be given about the construction of Russia's latest turboprop transport, the Antonov An-24, which is nearing completion of its manufacturer's flight trials.

The An-24 is intended primarily for use on local services, and this dictated its configuration and performance. A high-wing layout was chosen to reduce the possibility of damage to the 2,000 s.h.p. Ivchenko turboprops while taxying on unprepared airfields. The undercarriage has twin wheels on all units.

The crew of four comprises pilot, co-pilot, navigator and one stewardess and standard equipment includes "up-to-date instruments, command and communications radio and radio navigation aids."

Wide use has been made of new constructional techniques and light, corrosion-resistant materials. Glass-fibre is used for trim-tabs and aerial fairings with bolts and screws in polyamide resins. (Polyamide resins do, of course, have similar applications in Great Britain.) The skin is attached to the spars and other structure by resistant spot welding and the welds are strengthened by a process described in the USSR as "cementing, the first known application of this technique in world aircraft engineering." It is claimed to reduce considerably the number of rivets required, to improve the sealing of the flight deck and cabin, and to reduce aerodynamic drag. [Redux was first used in 1943—Ed.].

The cabin is pressurized, air-conditioned and sound-proofed, and is fitted with reclining seats in four-abreast rows, with a central aisle. Plastics are used for furnishings and trim, the standard of *decor* being appropriate to the An-24's main role as an air-bus.

No dimensions have been given, but the cabin appears roomy and well-planned, with a luggage rack above the seats on each side and fluorescent lamps along the entire length of the ceiling. The standard version has a galley, cloak-room, toilets, and baggage and freight compartments. The last-named must for the most part be located between the main cabin and flight deck, as the passenger entrance door is to the rear of the cabin, in line with the front of the dorsal fin.

There is much still to be learned about the An-24, notably its precise size and weight; but it will be argued that Oleg Antonov may have come as near as anybody to producing that much-needed, elusive, not-too-big and not-too-sophisticated DC-3 replacement.

BOEING'S TRANSPORT HELICOPTER

BOEING'S transport helicopter conversion of a US Army Vertol YHC-1A—the Boeing-Vertol 107 Model II—made its first flight at Morton, Pennsylvania, last Tuesday, October 25. The helicopter is now embarking on its FAA commercial certification programme, being the first twin-turbine type to do so.

In the conversion, a new transmission and rotor system is associated with an uprating of the dynamic system from 1,700 to 2,300 h.p. Power is supplied by two General Electric CT58-8 shaft turbines. Other changes include a new forward pylon to improve directional stability, a redesigned control system, revised electrics and various modifications to the airframe. Among the last-named is a 23in addition to the fuel tank sponsons on either side of the rear fuselage. This is said to improve stability on water; no other flotation gear is required for water-borne operations.

The 107 Model II is a development of the prototype Lycoming T53-powered Vertol 107 which first flew in April 1958, and was demonstrated last year at the Paris Salon. Intended for both civil, and military amphibious-assault, operations it carries 26-30 passengers (or troops) and has a design cruising speed in excess of 155 m.p.h. In the transport version, ten of which have been ordered by New York Airways, a removable baggage unit is installed in the rear cabin area. It "rolls out like a drawer" for luggage handling. Interior design has been undertaken by Walter Darwin Teage Associates, who have been responsible for some Boeing 707 interiors.

Vertol Aircraft Corporation were taken over by Boeing on March 31 this year.

In the DH Trident mock-up fluorescent lighting is set behind the luggage racks so that no direct light reaches the passengers. Twenty-eight four-foot fluorescent tubes for cabin illumination are being supplied for each Trident by Philips Electrical

A new look in aircraft sub-assemblies is apparent in this view of the wing torsion-box centre-section of the VC10. All detail parts of Vickers' latest transport are finished in pale grey epoxy paint

NEW TRANSATLANTIC CUNARDERS?

AS forecast in *Flight* for September 23, Cunard Eagle have now applied to operate passenger services across the North Atlantic, though not as yet to New York. Their application, which will presumably be contested by BOAC before the Air Transport Licensing Board, is made to the Air Transport Advisory Council today, November 4.

The application is for a daily Britannia return service from London and/or Manchester and/or Glasgow to Philadelphia and/or Baltimore and/or Washington for a period of ten years.

EVIDENCE FOR THE ELECTRA ENQUIRY

ACCORDING to a preliminary CAB report on the Eastern Air Lines Electra accident at Boston on October 4, No 1 engine was shut down and feathered with both automatic and manual devices actuated before impact. It had been "subjected to extreme over-temperature conditions resulting in severe deformation and damage to [its] combustion section prior to shut-down." Both Nos 1 and 4 engines had starling feathers in their intakes and oil coolers. The No 1 intake had a half-inch deep dent, 4in by 7in; this was made before impact with the water "by a non-metallic object." Particles of "metal, carbon, marine life, feathers, tissue and fabrics," some not completely identified but others described as starling remains, were taken from engines 1, 2 and 4 for analysis, but none was found in No 3. Feathers had been found in all three of the four generators so far stripped.

Reports by some 45 eye-witnesses suggest that the Electra lifted off about 2,500ft from the end of the 7,000ft runway, rose to 30-40ft in a level attitude, there rotated to a normal climb attitude and began to climb. At this point some witnesses saw a "puff of smoke" from engine No 1; others saw a "ball of fire" from No 2. However, Nos 2, 3 and 4 were all apparently developing considerable power at impact, propeller pitch being 38-39°. The aircraft made a flat 45° turn, appeared to settle—losing about half of its 275ft height—and then dropped its left wing as though entering a wingover. It regained some altitude, then fell as the nose dropped to near-vertical. It crashed slightly left wing first. The date for the public enquiry had not been fixed as this issue went to press.

BREVITIES

In the Handley Page annual report, received as we go to press, Sir Frederick Handley Page says that Herald research and development cost written off to date is £3,080,706, and production cost £1,514,422. Recovery of all expenditure is dependent on the sale of at least 80 aircraft, which the company hopes to achieve by 1963. Profits will begin to accrue at about the 25th aircraft.

BOAC Comet 4s are now using the new Sao Paulo airport at Viracopos. Hitherto they have used a military base near Sao Paulo.

The Air Registration Board announces the issue of notice to licensed aircraft engineers and owners of civil aircraft No 59, issue 1, October 20, 1960.

It is reported that the Argentine independent Transcontinental is to operate three Viscounts on local-service routes from Buenos Aires to Montevideo and Asunçion and within Argentina. The airline has also opened a three-times-weekly Britannia service between Buenos Aires and Santiago.

Changes in the presentation of *Aerad Flight Guide* have been made. For example, approach and landing charts will henceforth be printed singly on sheets 10in by 6½in, a larger and therefore more legible format. Some other changes are made "to cope with the ever-increasing amendment problem brought about by the unregulated and uncoordinated day-by-day alterations published by aeronautical authorities throughout the world."

The first prototype YS-11, the new Japanese twin-Dart feederliner being built by NAMCO (Nihon Aeroplane Manufacturing Co) is due to be completed at the end of 1961, and the first production aircraft is scheduled to go into operation on Japanese domestic routes during the second half of 1963. The second YS-11 should fly early in 1962, and two others during 1963. (A note on Japanese Government financing of the YS-11 appeared on October 7, page 563.)

A new agreement has recently been concluded between Air France and UAT. Supplementing that signed in February when "Air Africa" was formed, it is said to "lay down the basis of a very close co-operation in the field of commercial organization and operational programmes." Air Africa takes over Air France's and UAT's joint operations within Africa. Apart from operational activities, Air Africa would be able to provide African states "with any aid they may require in commercial aviation."

BEA's Comet 4 fleet was grounded for 12 hours on October 29 while the nose legs of all aircraft were checked. This followed an accident at London Airport in which the nose wheel axle of a Comet 4B fractured. The aircraft slid forward for a few yards but was not seriously damaged. Similar crack detection tests to those carried out by BEA on their own aircraft and 4Bs belonging to Olympic Airways have been carried out by BOAC. None of the latter's flights was cancelled or delayed.

A BKS day return fare of £1 19s between Newcastle and Leeds/Bradford has been approved by the MoA—6d cheaper than the second class rail fare. The BKS service takes 30min compared with 2hr 7min by rail.

KLM has obtained traffic rights in Las Palmas, and this Canary Islands tourist resort is to be added to the airline's Electra network tomorrow, November 5. It will be included in the new service Amsterdam - Zurich - Casablanca - Las Palmas - Conakry - Monrovia.

With effect from November 1 Mr K. G. Wilkinson relinquished his post as BEA's fleet planning manager, and transferred to the engineering department. On the same date Mr P. W. Brooks, for some years technical assistant to Lord Douglas, BEA's chairman, became fleet planning manager.

The West German Minister of Economics, Herr Ludwig Erhard, is reported to have said that the Government is ready to negotiate with the manufacturers with a view to assisting the financing of the HFB 314 jet transport. According to a West German source, Hamburger Flugzeugbau require £3.4m to £3.8m.

The PNdb as a standard unit of measuring aircraft noise has been agreed by an international group working under the ægis of OEEC. The chairman of the study group was Dr G. E. Bell of the Ministry of Aviation (which already recognizes the PNdb). Other countries represented were Denmark, Germany, Italy, the Netherlands, Sweden, Switzerland, and the USA.

BOAC continues to boost its traffic on the western routes: figures just issued by the MoA show that load ton-miles during the twelve months ending July 1960 went up by nearly 35 per cent; passengers by 33 per cent; freight by 47 per cent; and mail by 35 per cent. Western load factor fell by nearly three percentage points to 52.3 per cent. UK scheduled air traffic as a whole during the twelve months up to July went up by 22 per cent.

According to a US source Mr William Patterson, president of United Air Lines, says that he will buy 40 Boeing 727s "as an absolute minimum." As soon as "a few details are worked out," he says, "the order will be signed." Meanwhile it is reported that American Airlines will decide by the end of the year whether to buy 25 Caravelles or 25 Boeing 727s. The other operators interested in the 727, as already reported, are Eastern and Pan American.

The latest airline to send its DC-7Cs to Douglas for conversion to DC-7F all-cargo transports is Alitalia. Two conversions have been ordered. Meanwhile three of the DC-7Cs recently acquired by Riddle Airlines are to be converted by Douglas, plus an option on seven more. Average conversion cost per aircraft is about $320,000. It is reported that Pan American are to convert 10 more DC-7Cs to incorporate mechanized loading. TWA report that work is now in progress on the conversion of six L.1649As to all-cargo use.

Now for Eurocontrol?

Background to a Royal Flight

THE near miss experienced last week by the Queen's Comet 2 (see page 688) highlighted the essential ATC problem—separation, particularly of civil and military traffic.

As shown in the table below, there have been six collisions between civil passenger airliners and military aircraft in the past two-and-a-half years, costing 191 lives.

The Nevada Desert and Brunswick collisions in the USA shocked Americans into making fundamental changes in their air law, and led directly to the creation of the Federal Aviation Agency. This is a *civil* authority, with an ex-USAF general at its head, and it has a mandate to implement the joint control of civil and military traffic.

The BEA Viscount-Italian Air Force Sabre collision near Naples two years ago likewise shocked Europe into recognition of the urgent need for unified air traffic control. That tragedy accelerated the plans for Eurocontrol, the initiative for which came from the six members of the European Common Market—France, Germany, Italy, Belgium, the Netherlands and Luxembourg. Britain has participated from the earliest days.

Eurocontrol envisages unified control of upper European airspace from a common centre. Last June the then Minister of Aviation, Mr Duncan Sandys, announced in Rome the British Government's approval of the draft convention and protocol for establishing Eurocontrol. Mr Sandys described it as "essential" in view of the expanding volume of traffic.

Last week's near miss was one of more than 1,000 (the exact figure cannot be determined) reported during the last year in Europe; there are said to have been 246 in West Germany alone. The Queen's narrow escape has emphasized, as perhaps nothing else could have done so dramatically, the urgency of the need for Eurocontrol.

CIVIL/MILITARY FATAL COLLISIONS, 1958-1960

Date	Aircraft	Location	Fatalities
May 20, 1958	Capital Airlines Viscount and National Guard T-33	Brunswick, Maryland	11
April 21, 1958	United Air Lines DC-7 and USAF F-100F Super Sabre	Nevada Desert	49
October 22, 1958	BEA Viscount and Italian Air Force F-86F Sabre	Naples	31
December 22, 1959	VASP Viscount and Brazilian Air Force T-6	Rio de Janeiro	32
February 25, 1960	REAL DC-3 and US Navy R6D	Rio de Janeiro	65
March 16, 1960	All Nippon Airways DC-3 and Japanese Defence Force F-86D Sabre	Nagoya	3
		Total fatalities	**191**

Meanwhile, accepting the fact that each nation's ATC is still sovereign over its airspace, and that the UK has no jurisdiction outside its own Flight Information Region boundaries, a number of questions have to be asked:—

What are the procedures for the operation of a Royal flight?

Within the UK, the procedures are clearly laid down in Chapter 12A of the UK *Air Pilot*, pages 101-103. The Purple Airways system is brought into operation. Notification by the Ministry of Aviation goes to all operators of aircraft, British and foreign, by means of a class 1 Notam. The procedure is clearly laid down and strictly enforced, and it is not in any way involved in the present dispute. But purple airways do not extend beyond the United Kingdom FIR.

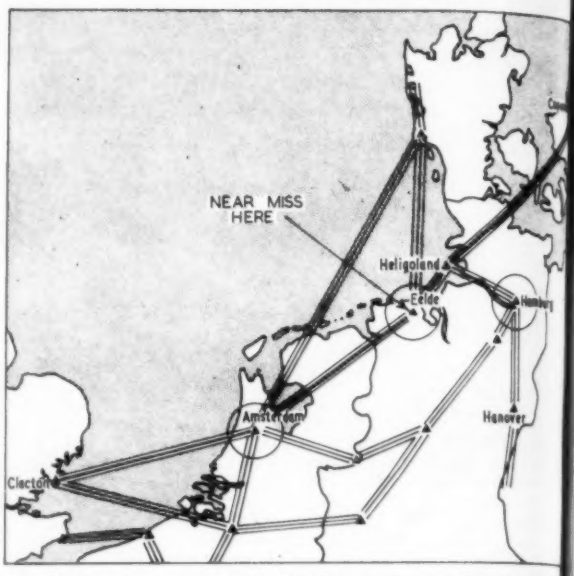
What are the procedures for the operation of a Royal flight outside the UK?

In the case of an RAF flight, responsibility rests with Transport Command* (1) to draw up the flight plan (which *Air Pilot* prescribes shall always be in accordance with IFR) and (2) to notify NATO Command and the civil and military aviation authorities of the countries over which the flight is to pass.

Notification is made *via* diplomatic channels, i.e. the UK air attachés concerned, with the request that arrangements should be made to ensure a safe passage for the Royal aircraft. Thus, in this instance, both the Transport Ministry and the Defence Ministry in Bonn would have been notified, as would the appropriate Government departments in Denmark and the Netherlands.

When the flight plan has received the assent of the countries concerned, the UK issues its Notam—which of course applies to UK airspace only.

**The Queen's Flight, a branch of RAF Transport Command, would obviously be most closely concerned.*



The RAF Comet was reportedly at 35,000ft on upper Red One in the Hanover FIR when it reported the near miss to Amsterdam

Did RAF Transport Command take the action just outlined?

Though this question is the subject of an official enquiry, there is no evidence to the contrary.

Did the foreign countries concerned take action on the UK notification of the Royal flight?

Again, this is the subject of an enquiry, but there is as yet no evidence that any international Notam was issued by the West German civil aviation authorities, or indeed by the Danish and Dutch civil authorities. However, all civil ATC centres in the countries concerned were informed.

Were all military units notified of the Royal flight?

According to a West German Defence Ministry spokesman, all Luftwaffe squadrons and formations were informed of the Comet flight. This would mean that German pilots *who were not on NATO-assigned exercises* would have been told in their pre-flight briefing to keep clear of airway Red One at the times and places notified. If they were on NATO-assigned exercises notification would have been passed down from NATO through the Allied Tactical Air Force to all the Allied squadrons in the ATAF, and the aircraft would have been under NATO control and radar surveillance.

Were the fighters under NATO or national control?

The aircraft could have been under either Luftwaffe (assuming that they were Luftwaffe, which seems to be accepted by the Germans) or NATO control, depending on whether they were on a Luftwaffe mission or a NATO mission. This suggests that, far from there being unified civil/military air traffic control in Europe, there is not even unified military control.

* * *

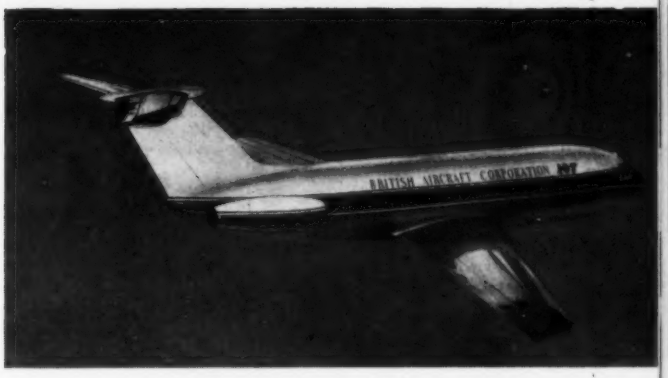
The fighters concerned should not have been near a civil airway anyway, let alone near a Royal flight on a civil airway. It is of course extremely difficult for a fighter pilot to know where he is, especially if he is on a combat training mission. He can obtain a fix by VHF communication with the ground, but this is out of date by the width of a civil airway in less than a minute. He would have an ADF radio compass, but this gives line bearings and not fixes. The possibility of navigating a jet fighter accurately is remote, *unless* it is under radar control.

It has of course been known for civil traffic to be deliberately buzzed by fighters. A *Flight* staff member on board a Comet 4 on a civil airway over Formosa last year photographed a close interception by a Nationalist Chinese Sabre (February 6 issue, 1959, page 176). A fighter pilot could be excused for being accidentally off course, and excuses could be found for the possibility that he was not under radar control. But there could be no excuse for a deliberate interception of an aircraft on a civil airway.

The final question must be: How quickly can technical agreement on the selection of a standardized European ATC system be reached to enable the early implementation of Eurocontrol?

Ansett and TAA Ideas on the Jet Airliner

BY STANLEY BROGDEN



The BAC-107 short-haul jet would make a suitable partner for the larger medium-haul VC11 from the same stable. Both are projects only but, the writer remarks, they are being forcefully promoted

WHILE the rest of the world operates jet airliners on domestic routes Australian domestic airlines can only watch and plan. At the moment it would appear that 1964 is the accepted year for the introduction of jet services here in Australia. The internal operators are therefore watching and weighing the promises of aircraft manufacturers over the next fifteen months; for by Christmas 1961 they must have made up their minds about their next choice of equipment.

One of the very difficult aspects of this choice is that the Government hold on airline policy, through its rationalization system, is almost sure to force the two operators to select the same equipment —or at least to order it. For TAA and Ansett-ANA are today as far apart in their fundamental thinking on the jet airliners they need as they were about the turboprop types now operating.

Consider the late 1950s. As far back as 1956 the operators were very far apart in their reactions to the equipment being offered. TAA was interested in the Caravelle from the beginning; Mr R. M. Ansett and his Ansett Airways team liked the Electra. This was before the Ansett-ANA wedding. ANA was in a bad way and could not seriously consider new equipment. It had made what turned out to be a disastrous decision when it decided to order DC-6s and DC-6Bs, for the top-level philosophy was to have a type which could not only operate on all route-lengths but also carry anything human or inanimate with similar profits. The ANA technical people wanted the Airspeed Ambassador and/or the Vickers Viscount, but this was overruled at the top policy level. There was also the factor of the late Sir Ivan Holyman's extreme patriotism: he wanted DC-6s because they could form a wartime troop carrier force with sufficient range to operate into Asia or the Middle East. That doomed ANA. It was a tragedy for both the UK industry and ANA that the late Sir Ivan was above all a Douglas man. A good ANA order might have saved the Ambassador project: Viscounts might well have saved ANA, if anything could have done.

Mr Ansett stayed by his Electra preference when the amalgamation came. When the Government's policy of two equal operators was decided he told the Government and the Department of Civil Aviation the Caravelle was a crazy idea. He had reasons: two engines, too much pioneering effort, unlikely profit. Luckily for him, Qantas advisers also favoured the Electra as against the Britannia or a medium-range jet.

TAA Wanted Jets

That meant two of the three major Australian operators were for the Electra. Qantas was the most powerful of the three in political influence, and still is. The days of great TAA political pull have gradually faded. TAA's management, technical and administrative, is not the force it was in Canberra in the 1946-54 period. That could return with a Labour Government, of course. In the early 1950s TAA's opinion might have been paramount, even under the Liberal-Country Parties Government, but TAA influence was sadly affected when it advised BCPA to order Comet 2s. In 1958 TAA was alone in wanting jets on domestic services. Ansett-ANA wanted Electras on domestic routes and Qantas wanted Electras on the shorter-range international routes, such as Sydney - Hong Kong. (One of the puzzling aspects of the whole affair, by the way, is the mystery of what happened to the very interesting offer made by Bristol to the Government, which is said to have paralleled the Electra deal in every way.)

It was obvious that the Government either had to force Ansett to submit to TAA's introduction of jets or to force TAA to drop the jets. The Government did not want jets on domestic services because the airports were not prepared for them. Essendon (Melbourne) in particular was a problem, for the Labour Minister for Civil Aviation in the late 1940s had overridden departmental advice and insisted that land be sold to housebuilders right to the edge of the airfield. This was political; and the present Government's fear of noise was political. It still is. Both wanted votes. There was also the question of handling the jets in the air: the Department was far from keen about jets until the mid-1960s, when the turboprops had been digested and lessons learned from operating aircraft in the 300-400 m.p.h. bracket could be assessed. Nevertheless, TAA say that the Department did tell them on an operating level that it would permit some two-dozen Caravelle operations a week in and out of Essendon. Had Mr Ansett agreed to buy Caravelles, four would have been permitted on Australian routes from the Department's viewpoint (two for each airline). The Government would probably have agreed, for another factor was that everybody knew if TAA put on jets and Ansett put on Electras then TAA would simply get the business. The Government just would not agree to TAA having jets and Ansett-ANA having none.

To cut the knot, the Government proposed that both operators should be confined to Viscounts 800s and Friendships until the mid-1960s. (Qantas were aside from this.) A decision was taken on these lines and TAA would have accepted it, perhaps reluctantly. Ansett-ANA refused.

Mr Ansett pointed out that he could only renew ANA (in which morale was very low) as Ansett-ANA by the introduction of equipment which would give the new airline a fillip in the public mind and prove to the doubting ANA employees they really had a future. He had to have a big and modern and efficient money-maker—the Electra. As Qantas picked this type, the Government had to agree, and the decision was taken that all three Australian operators would buy on the dollar market. (Behind all this was, of course, a mighty sales effort by Lockheed, which included a high-level team, and almost no sales effort by the French.)

The Electra Makes Money

Mr Ansett was unfortunate in that his team took for gospel the promises made by Allison salesmen and did not foresee the Allison engine and Electra airframe troubles. In spite of the delays and the unhappy history of the type this year both operators are making money with Electras, but the effect of the troubles on passengers has been to give the industry a bad name. The Electra must live this down. But the facts are that in spite of all the money lost to the operators by the engine troubles and the airframe crisis, the Electra is a moneyspinner here and will be a bonanza when fixed. The Viscount of whatever mark is not in the same street economically (at least in Australia); so it is overall a fortunate thing for the industry, if not the passengers, that the decision to stabilize fleets on the 800 was not made. The public will forget the Electra troubles in time.

There is no question, also, that TAA would have made the Caravelle pay. TAA would have had an enormous advantage in offering jet travel, but they would also not have suffered the troubles they have faced with the Electras. This is not the only reason for regretting the Caravelle decision. If it had been introduced last year the Government would have been compelled to proceed with Tullamarine jet airport near Melbourne. As it is, Tullamarine is just a piece of real estate the Government now owns. No work will be done this financial year (to June 30, 1961) and not much will be done in the next. The Government would have been forced to bring up other major airports to jet standards and to push along the modernisation of airways systems for jet handling.

Public opinion today is forcing the jet issue. Both operators have told me they realize they must have jets on their services by Christmas 1963—that is, the opening services. Neither operator particularly wants to do this that early, for the present Viscount/Friendship/Electra fleets are on five years' amortization, and that goes into 1964. The airlines would prefer late 1964 at the earliest, but they accept Christmas 1963 for the introduction, with full jet operations in early 1964.

The key factor is Essendon-Tullamarine. There is no question that at this stage jet operations in and out of Essendon would create public uproar, but only in the immediate vicinity and only in one or two electorates. There would be more public demand

The D.H.121 Trident could be paired off with the smaller Hawker Siddeley Group jet, the Avro 771, to meet the needs of the TAA/Ansett-ANA domestic market from the mid-sixties

Ansett and TAA Ideas on the Jet Airliner . . .

in the Australian community at large—particularly in the airline-user sector—to have jets on the domestic services. Comet 4s are operating into Essendon several times a month on restricted weights on BOAC services without much local joy.

The airline operators must choose; and evidently, from what they tell me, they have decided on jets regardless of Essendon. In fact, they have a notion of forcing the Government's hand on Tullamarine by going ahead with jet orders. Public opinion would not allow the Government to deny jets to the airlines by the time they want to order, in about 14 months from now. (The Department of Civil Aviation wants to proceed with Tullamarine, but has no funds and would be glad to see the Government's hand forced.) Government insistence on parity of equipment may mean that the two operators will be forced to agree on a common type, though it would appear to be at least possible that agreement could be reached to permit the two airlines to buy different types of similar work potential and availability. That depends. This situation is all the more amusing because the two operators have radically different viewpoints on the very fundamentals—as of old!

TAA, whose views on these matters are based on the deep thinking of their technical director, Mr John L. Watkins, have it in view that they might have two types of jets. One would be of medium range, to supplement the Electra and Viscount 800 on the trunk routes; some Viscount 700s would then be sold. This type must be economic on the Melbourne - Adelaide - Perth, Sydney - Adelaide, and Melbourne - Brisbane routes, as well as on the basic bread-and-butter Melbourne - Sydney run of 480 miles. Some 50 per cent of all the income received by the domestic operators comes from the Melbourne - Sydney - Melbourne highway, remember. The type in this bracket must be economic in the 500/1,500-mile ranges. TAA believe that the most promising types on offer are the Trident and the Caravelle 8, with the Boeing 727 a possibility. The Trident would be more attractive with two engines and TAA would also like a rear ventral door for the passengers, as would be possible on the Mk 2 version. The Mk 1 Trident is, however, the one which TAA are considering. Two Rolls-Royce RB.141s would make this a more attractive proposition. For the Perth run, a centre-wing tank would give the required range. The Mk 2 is rather large for the Melbourne - Sydney run, which needs frequency of operation.

TAA say they want frequency and flexibility—frequency on the 500-mile runs, but flexibility to cover the longer runs. One of the basic factors in considering types for Australian airlines is the great range of traffic volumes on different routes. TAA are also watching the Tu-124, not from the viewpoint of a buyer, but because it is first in its field and the airline likes to keep well-informed. They have had the same attitude towards the Il-18.

Impressed with the Caravelle

At the moment TAA have an open mind, for they realize that at this stage it would be foolish to have fixed preferences, but there is no question that they have a warm regard for the Caravelle 8. They have always been impressed by the Caravelle as a piece of engineering, having watched that design from the early period. They have great respect for the Trident design, but are not keen on three engines; they would like to see a ventral door, and there is, of course, the question of seating. There would need to be a vast reduction in rates here for the customers to accept six-abreast seating. When BEA put five-abreast seating in their first Viscounts years ago, Australians who flew in them were horrified. Out here, five-abreast has been accepted by the tourist-class traveller, but six-abreast would need real selling. The Boeing 727, which has been watched throughout by Mr Watkins and his people, would in my personal opinion be the third in line.

The second jet type would be in the 200/500-mile bracket, to do the job now performed by the Friendship/Viscount 700 fleet. No jet airliner now flying can fulfil this need (other, possibly, than the Russian Tu-124), but TAA are interested in the BAC-107 and the Avro 771—if these aircraft are ever in fact put into production. The Convair 60 would have a definite appeal but it is understood here that it is now another dead duck. The recent visit by the Vickers sales team with the BAC-107 specifications had a big effect at TAA, Mr Watkins telling me quite frankly that this was the most sophisticated presentation ever made of any British aircraft. The trouble is the engine, which is not even turning over yet. TAA do not see how any manufacturer can promise to have a brand-new jet engine operating adequately three years after it is first run. This would seem to be the barrier to any present TAA interest. The philosophy of the aeroplane does attract TAA. The timing, 1964-65, is good. The idea of operating a jet which offers 10-15 per cent lower direct costs than the Viscount is most attractive.

Ansett-ANA have not devoted the same amount of man-hours of study to jet replacements as have TAA because they have a more conservative approach to new equipment—as was shown in their attitude to the Caravelle 8. So far they have been of opinion that there was no sense in the two-types-of-jet-aircraft thinking which has been done at 339 Swanston Street. This may be because they have only just decided to start real investigation of the jets. They have until now been thinking mostly of the Boeing 727 as an Electra-Viscount 800 replacement in the 1965 period, keeping Friendships on the short routes until 1975. They have not liked the two-engine philosophy. However, the Douglas team which visited Australia in September changed the Ansett-ANA attitude a good deal: they are now very impressed with the Caravelle 8 and even more impressed with the Caravelle 14. The Mk 8 could very well be in their requirement category.

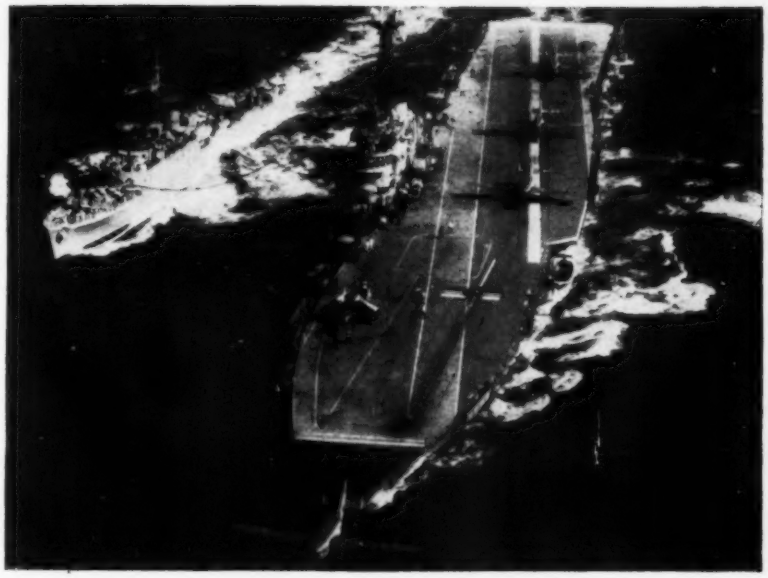
In mid-October the whole Australian outlook on jets was changed by a visit of the Vickers team, which has suggested a far-seeing and ambitious plan that is now being worked out in detail as a definite proposal by the Vickers people in England. This is probably the finest deal-proposal ever made by any British manufacturer and it could mean a new era is dawning in the UK's sales approach in the airline industry—one that is long overdue, I think.

Combined VC11 — BAC-107 Fleet

The suggestion is that the two Australian domestic operators buy a combined fleet of VC11s and BAC-107s to replace Electras and Viscounts on all but the most minor routes from 1964. Some £36,000,000 is the figure I have heard. Now this is a fascinating idea, for both operators have been agreed to date that the VC11 would be too big, but the Australian airlines have been told it would have 100 seats. This would be a fair rise from the Electra seating, but taking into account the 10 per cent annual rise in business here which would appear to be customary in the airline industry, the introduction of a 100-seat type might be made without losing frequency. The combination of two jet types from the same stable has obvious attractions. Ansett-ANA seem to have been more impressed by the proposal than TAA at this stage, but the detailed plan now being drawn up by Vickers could change this. It will be very interesting to see what reaction the plan brings. It would solve TAA's problem of securing Government permission to buy two types, which could not be secured if Ansett-ANA were wanting only one type. On the other hand, with the changing attitude at Ansett-ANA, both airlines might well decide on a Caravelle 8/BAC-107 combination between them, or for that matter a Trident/BAC-107 union. It is a tragedy that the conditions operating within the British industry have kept the Trident back: that aircraft should be a year ahead of its present state. The Boeing and Caravelle people have the advantage there.

TAA's jet thinking will be coloured by the result of Mr Watkins' tour of Europe and the USA next year—he is due to go away in 1961, for he makes regular visits. He will come back with proposals. Ansett-ANA will be making similar investigations next year with their jet-study team. Both airlines will have definite ideas about 12 months from now.

What does encourage a lot of us here is the possibility that the new broom in the UK industry may have done such good sweeping as to uncover a new approach to sales. The British industry has not been helped here over the years by its sales approach. One manufacturer recently made a prime mistake when one of its top executives made it plain to one operator here that any choice of a new aircraft was too important a decision to be made by anybody but the Government. I ask you!



HMAS "Melbourne," flagship of the Australian fleet, being refuelled at sea. Embarked in her are Sea Venoms of No 808 Sqn and Gannets of Nos 816 and 817 Sqns

Australia's Fleet Air Arm

THREATENED DEMISE OF A GALLANT SERVICE

CAN Australia do without a Fleet Air Arm? The present Australian Government apparently thinks it can. In November last year the Minister for Defence, Mr Athol Townley, said that the present generation of Royal Australian Navy aircraft would not be replaced after they reached the end of their Service life in 1963. The Government's reason for this decision was economic: money available for overall defence was insufficient to include the purchase of a new carrier capable of operating swept-wing aircraft, with which the Australian Fleet Arm would need to be equipped to remain an efficient fighting force.

Instead, the Navy's part in protecting Australian sea-lanes would be carried out with submarines and small surface craft; and equipment of the RAAF with a second squadron of Lockheed Neptunes has indicated that land-based aircraft are to play an increasing part in maritime operations.

The Government's reasons for taking this decision are understandable: Australia, with a small population, has limited resources; on the other hand, she has a vast territory to defend and has engaged herself to assist the South-East Asia Treaty Organization. She cannot afford to arm to the teeth, but must have teeth; what kind can she afford?

As far as air power is concerned, the present Government has clearly decided to put its money on the RAAF: a squadron of Lockheed C-130 Hercules long-range transports has been purchased; the Neptunes already mentioned are replacing Lincolns for long-range maritime patrol duties; and a mission has been touring the world to seek out a suitable replacement for the Sabres at present used on intercepter duties. In the meanwhile, helicopters have been purchased for the Australian Army. The Royal Australian Navy, which has been built up around the carriers *Melbourne* and *Sydney*, has been left out in the cold—on the grounds that re-equipment would be too costly and is of insufficient priority.

Naturally there is disappointment at this decision. The RAN point of view on the value of naval aviation might be summed up in words used by its then Chief of Staff, Vice-Admiral Sir Roy Dowling, who in September 1958 wrote: "The aircraft carrier is vital not only for the defence of the Fleet but as a means of deploying air power outside the range of land-based aircraft, or in areas where there are no airfields suitable for modern jet aircraft." These words have an especially strong significance in relation to Australia, with her large land area and endless coastline, providing the perfect argument for air defence from mobile seaborne bases. Availability of a carrier in an area where suitable airfields may be few or non-existent ensures that continuous and concentrated air support can be provided for operation against submarines or in support of a beach-head. This concentration of effort could not be provided by shore-based long-range, maritime aircraft or fighters.

Further, the Australian Navy might justifiably argue that whereas it is easy to close down a Service it is another matter building one up to a state of operational effectiveness. Especially is this true of a fleet air arm which involves not only aircrew and groundcrew training but the application of avia-

Commissioning day for the Sea Venom and Gannet squadrons of HMAS "Melbourne" at RNAS Culdrose, Cornwall, in 1955

AUSTRALIA'S FLEET AIR ARM . . .

Gannets from Nowra, NSW, the main land base for RAN aircraft, over the New South Wales coastline near Port Kemble. Nowra has a satellite, Jervis Bay, about 20 miles away

tion techniques in a maritime environment and special problems of seamanship. A Ministerial pronouncement of a few minutes' duration may put an end to years of accumulated experience; but if the Ministerial decision is as suddenly reversed, the process of rebuilding to an equivalent standard of skill may take many years; pilots cannot be trained overnight, any more than ships can become operational in a day.

Though the Australian Government's decision not to re-equip the Australian Navy with more modern aircraft is understood to be final, the RAN is fighting hard to stay in aviation. One solution it has in mind to propose is the re-equipment of HMAS *Melbourne* as an anti-submarine carrier operating helicopters. Possible types for this purpose would be the Westland Gnome Whirlwind or the Vertol 107.

RAN determination is understandable, for it has a proud (though short) tradition of Naval air operations, having been tried under fire during the Korean action when HMAS *Sydney* played a gallant and distinguished part in operations. This ship, which was the Royal Australian Navy's first aircraft carrier, originally belonged to the Royal Navy as HMS *Terrible*. She arrived in her new home waters in May 1949 and embarked the RAN 20th Carrier Air Group, consisting of two squadrons, Nos 805 and 816 (Sea Furies and Fireflies). Subsequently she returned to England and embarked the 21st Carrier Air Group, likewise of two squadrons, Nos 808 and 817 (Sea Furies and Fireflies). There was a strong competition spirit between these two groups, their friendly rivalry contributing much to the development of an efficient flying force, which was soon to be tested in action.

For in September 1951 a Dominion aircraft carrier was sent into action for the first time, HMAS *Sydney* relieving HMS *Glory* as carrier representative of British naval forces in Korean waters. How well she sustained Royal Naval traditions the battle statistics show. Two squadrons of Sea Furies (Nos 805 and 806) and one of Fireflies (817) were embarked, and on October 11 they helped to set up a light fleet carrier record by flying 89 sorties against troop concentrations and store dumps on the east coast of Korea. In two consecutive days' operations, they flew a total of 147 sorties.

Sydney continued to play an active role in the Korean theatre until the end of January 1952, sailing more than 30,000 miles in operations and mounting 2,366 sorties from her flight deck. For this service, three DSCs, a Bar to the DSC and a DSM were awarded.

After the Korean War, she had an opportunity of showing the Australian flag in peaceable fashion, first in England during the Coronation celebrations of 1953 (No 817 Sqn taking part in the fly-past over the Naval Review at Spithead) and subsequently around the world on her return home via America and New Zealand.

In the same year, the Royal Australian Navy acquired a second carrier on loan, to serve in the interim period prior to re-equipment with jet and turboprop aircraft: this was HMS *Vengeance*, which temporarily became HMAS *Vengeance* and was initially commanded by Capt H. M. Burrell, now Chief of Naval Staff of the RAN. She participated in routine anti-submarine exercises and patrol activities, and acted as part of the escort for the Queen and the Duke of Edinburgh when they visited Australia in the *Gothic* during their world tour. Then in 1955 *Vengeance* returned to the UK and was handed back to the Royal Navy, with the reputation of having been one of the happiest ships in the RAN. Aboard on her UK voyage she carried the crew for HMAS *Melbourne*, formerly HMS *Majestic*.

With *Melbourne* the Australian Navy entered on its second (and, as things look now, possibly final) generation of existence. She was at that date—it was March 1956 when she left Portsmouth for Sydney—the most modern carrier of her class in the world, with angled deck, steam catapults and Mk 12 arrester gear. Embarked were her jet and turboprop aircraft, Sea Venoms and Gannets, with the aircrew of their respective squadrons—808 (Venoms), 816 and 817 (Gannets)—who had been training in the UK for the previous eighteen months.

Melbourne has since been the flagship of the Australian Fleet, and it is on her replacement—apparently considered too costly to be a practical proposition—or her conversion that the future of the RAN now largely turns. She has annually participated with other SEATO naval units in exercises by the Far East Strategic Reserve, and has shown the flag in Pacific countries like Japan, Hawaii and Indonesia. She has maintained an accident-free record of deck-landing operations, and her squadrons recently earned praise from the Australian Minister for Civil Aviation. After attending an air display at Bankstown, NSW, he wrote to express his appreciation of the part played by *Melbourne's* aircraft. "The RAN section of this air show," he said, "apart from being a highlight of the afternoon, reflected great credit on the Service. I would be grateful if you would convey my congratulations to the squadrons that took part. Their impressive demonstration of precision flying indicated a high standard of training and operational efficiency."

But neither Ministerial bouquets nor a fine tradition can stand as arguments when there are stronger economic ones. Basically, the question is whether Australia can afford three air forces—the RAAF, the helicopter side of the Army, and the RAN. In that order of priority, and with the RAN requiring the huge expenditure of a new carrier to replace *Melbourne*, the official answer is "no." Nevertheless there seems to be an argument for converting *Melbourne* to an anti-submarine carrier equipped with helicopters.

A decision to convert *Melbourne* would ensure that the Australian Navy stayed in aviation, providing a continuity of experience if the day should come for a renewal of fixed-wing Naval air operations. Alternatively, if *Melbourne* goes, Australian Navy functions will be confined to submarines and small surface vessels. This will considerably reduce the Navy's effectiveness in contributing to Australian defence; but it is likely to be the case after 1963 unless meanwhile the Australian Government can be persuaded to give *Melbourne* a new role.

A Bristol Sycamore of the Australian FAA participating in a recent Combined Services display

Correspondence

The Editor of "Flight" is not necessarily in agreement with the views expressed by correspondents in these columns. Names and addresses of writers, not for publication in detail, must in all cases accompany letters.

Manchester's Lost Traffic

MIGHT I elaborate on Mr Bishop's letter (*Flight*, October 14) which bristled with inconsequential fact and, in a rambling sort of way, appeared to suggest Manchester Airport is in an eclipse?

Record freight and passenger figures are achieved monthly; internal feeder services from the North-West Coast and the West of England are swelling passenger loads on intercontinental flights; firms from as far afield as London are despatching air freight via Manchester; and there is now even a waiting list of freight agents wanting to open offices at the airport.

It is most unfair of Mr Bishop to suggest that Manchester is dragging her feet over necessary developments. The problem is simply that Manchester ratepayers are expected to subsidize an airport facility that is used by countless thousands of non-Mancunians—like Mr Bishop, whose home is in Cheshire—who benefit from this municipal enterprise yet contribute nothing but occasional destructive criticism. It is, therefore, only reasonable to expect the Ministry of Aviation to be more generous, particularly when public capital is poured into projects such as Gatwick the Grim.

Ringway at the moment is making a handsome profit, due primarily to its tough director, George Harvey—who unfortunately has to bear with political squabbling on his airport committee. But when modernization schemes have been paid for, the profit will quickly become a deficit. And while Mr Bishop is happily watching his Boeings, Mancunians may well be grousing about the heavy rate burden they have to shoulder.

Manchester AN AIR CORRESPONDENT

Aircraft "Anonymity"

IT is gratifying to learn that Lufthansa are naming their Boeing 707s and it is to be hoped that they will extend the practice to their Viscounts and Super Constellations: with all the literary, artistic and historical wealth of Germany on which to draw this should not be difficult. The anonymity in which these aircraft have moved hitherto is rather depressing.

Equally depressing is the current BOAC practice of painting only the aircraft type-name, and not an individual name, on the fuselage. Surely these fine machines deserve better than to be made as anonymous as buses?

Gp Capt "Jimmy" Jeffs and I were talking about the "C" class flying-boat *Clare* the other night. *Clare* was famous far and wide just because she was called *Clare*. Equally, passengers all knew *Golden Hind;* would they ever think of her if they only knew her as G-AFCI? If aircraft are really the successors of ships they should be given every encouragement to assume a ship's personality and individuality. This is rendered difficult at the outset by the rapidity with which crews change from one aircraft to another: it should not be rendered still more difficult by giving them only dull registration letters. For purely advertisement reasons, if nothing else, I would suggest BOAC think again.

Maidenhead, Berks T. W. E. ROCHE

The Hurricane and the Spitfire

AS one who also flew the Hurricane in the Battle of Britain, I cannot but agree with Wg Cdr Beamont's letter (August 26) on this aircraft and its performance.

In his letter in your issue of September 9, Mr McKee states he interviewed some three dozen British, Polish and German pilots. He has the grace to say a "few" of these had flown Hurricanes and possibly two could constitute this number. Since his book mainly concerned two squadrons—one of which, the squadron I served with, relieved in 11 Group on September 1, 1940—it makes one wonder if his investigations were carried very far.

Mr McKee's reference to the CR.42 as the best fighter in the battle is quite puerile, since that aircraft never took part in the battle and in the one raid in which it featured barely crossed the East Coast.

Mr McKee also states the Hurricane did not, as a front-line fighter, long survive the Battle of Britain. I for one was still flying one operationally in the Middle East in 1943, and I believe they were still hard at it even later in the Far East.

Nairobi, Kenya P. H. V. WELLS

"The Flying Years"

HAVING just finished reading the October 21 issue of *Flight*, I am pleased to report that, generally speaking, I enjoy reading your magazine. However, one thing bothers me, hence this plea.

It seems that among your readers are a couple of historical perfectionists, who are regularly afforded space in your correspondence columns to dig up all sorts of obscure, uninteresting snippets of so-called historical fact.

What a pity that *The Flying Years* is such an inaccurate series! I am sure that the BBC's wrong pronunciation of "Alcock" completely spoiled the programme for the "knowing" millions.

And what if poor old Tubby Gate's Sopwith Pup had Mary Jones' elastic tying up his map locker—not Victoria Prothergill's? Personally I don't give two historical hoots—I'd sooner see the space devoted to present-day happenings. But maybe I'm not old-fashioned enough.

London Airport, Middx G. DOORPOST

THE INDUSTRY IN BRIEF

Mr E. C. A. Goodwin, MIPE, has been appointed assistant production manager (military aircraft) of Vickers-Armstrongs (Aircraft) Ltd. His previous appointments have included the production managership of Hawker Aircraft Ltd.

Mr Andrew Green, of 68 Church Avenue, Pinner, Middx, is endeavouring to form an association or institute of service managers and would be glad to hear from those interested in such a project.

Jeltek Ltd, Green Lane, Hounslow, Middx, have issued illustrated pamphlets describing their different types of protective clothing for industrial and other uses.

Unbrako Socket Screw Co Ltd, Burnaby Road, Coventry, Warwicks, have published pamphlets describing and illustrating their range of screws, fasteners, bolts and nuts.

The Racal Organization, Bracknell, Berks, have received three major orders totalling £560,000 from the Canadian Department of Defence Production. The largest covers installation equipment for vehicle-borne military radio stations.

Vactric (Precision Tools) Ltd have stated that they are a completely separate company from Vactric Ltd, whose bankers recently appointed a receiver and manager. The statement adds that Vactric (Precision Tools) Ltd "will proceed as usual and continue to execute existing contract without any interruption whatsoever." The company's telephone number is now Belgravia 7000.

Texas Instruments Ltd, Dallas Road, Bedford, have introduced two new transistors, Types 2S301 and 2S302, the first in a range of silicon alloy junction devices. Their p.n.p. structure, it is claimed, makes all silicon complementary circuitry possible for the first time, using existing Texas n.p.n. silicon transistors. A particular feature of both the high-voltage version (the 2S301) and of the 2S302 is an extremely low saturation voltage.

A new product of the Dow Chemical Co is Chlorothene NU, an industrial solvent stated to be suitable for "cleaning a wide range of articles from small tools to large missile components." It has low levels of inflammability and toxicity; and the makers add that special inhibitors make it virtually non-corrosive to metals. To market Chlorothene NU and allied products a new Anglo-American company has been formed in collaboration with the old-established paint firm of Paripan Ltd; known as Penetone-Paripan Ltd, it has HQ at Egham, Surrey.

Mr N. E. F. Hitchcock, BSc, FInstPet, has been appointed laboratory manager of the main research establishment of the Castrol Group at Hayes, Middx, in succession to the late Mr P. W. L. Gossling. He is to occupy this post in addition to that of group development chemist, which he has held for nine years.

Recent changes announced by Nash & Thompson Ltd include the appointments of Mr R. G. Smith as contracts manager and Mr A. L. Lee as sales engineer for the Midlands and Northern England, responsible for the sales of metallurgical, process control, survey and electronic equipment. Prior to joining Nash & Thompson, Mr Lee was with Cooke, Troughton & Simms Ltd. Mr D. H. Yates has joined the company from A. H. Hunt (Capacitors) Ltd, as sales office manager and the position of chief inspector has been filled by Mr A. Ward, previously with Wayne Kerr Laboratories Ltd.

FORTHCOMING EVENTS

Nov. 4. Norfolk and Norwich Aero Club: Dinner and Dance.
Nov. 10. Radar and Electronics Association: "VHF Aerial Techniques," by C. A. Burgess.
Nov. 11. RAeS and IEE (joint lecture): "The Future of Electrics and Electronics in Aircraft and Guided Missiles," by Viscount Caldecote.
Nov. 16. Kronfeld Club: Film Show.
Nov. 17. Guild of Air Pilots and Air Navigators: Annual General Meeting.
Nov. 18. Institute of Navigation: Symposium on "Navigation for the Early Exploration of the Moon."
Nov. 18. RAeS: Sixteenth British Commonwealth Lecture, "The Story of Indian Air Transport," by J. R. D. Tata.
Nov. 21. RAeS Historical Group: "My First Ten Years in Aviation," by Sir Thomas Sopwith.

RAeS Branch Fixtures (to Nov. 11): Nov. 9, *Brough*, Seventh Sir George Cayley Memorial Lecture, "Forty Years of Aviation Journalism," by Maj Oliver Stewart. Nov. 10, *Isle of Wight*, Annual Dinner.

Straight and Level

I AM obliged to a reader at Harvard (a reader of this column, I must explain) for this clipping from the *Herald Tribune*: "Starting tomorrow, male passengers on Mohawk Airlines service between Buffalo and Boston and intermediate points will step aboard a DC-3 with a cabin reminiscent of Victorian days. Mohawk's new Gaslight Service will feature a stewardess dressed in a colorful Gay Nineties costume who serves free beer, cheese and pretzels—and sells good five-cent cigars. The cabins of the venerable planes have been decorated with antimacassars, red velvet curtains, brocade wallpaper and gilt-framed pictures. Two old carriage lamps are mounted on either side of the door leading to the crews' cabin."

Anyone for the can-can?

● A recent report from France reminded me of the old Hendon displays, when Virginias used to knock over giant skittles with practice bombs. A French fighter pilot based near Dijon was returning from target practice when a dummy rocket accidentally fell off his aircraft. It passed between houses and fell in front of a café, scattering the skittles which had been set up a few moments earlier. Happily no one got hurt.

Well bowled, sir.

● Mr William Patterson, president of United Air Lines, is reported to have said:—

"There is a fellow that has been breaking his neck to get me on the telephone. He has some sort of an airline that he would like to throw in on this thing. But let me say this: I have never done any business with some of these out-and-out speculators and shysters. And I do not intend to start now."

Yet another for my "retired aeroplanes" gallery—a Meteor 8 installed in a children's playing field at Aalborg, Denmark

Lakenheath fashion parade — see below

● I thought it was awfully decent of these *super* Sabre chaps at Lakenheath to invite Hamish Haute-Mode, Straight and Level's fashion adviser, to take the salute at their parade last week (picture herewith). The nautical number on the left Hamish found a shade East End, and the compact little crib-cracking outfit on the right the teeniest bit East Side. For the fuller figure, he tells me, the ensemble in the centre looks like carrying everything before it. Hamish was *quite* taken with the chaste two-piece second from right but thought it the weeniest bit common. Actually he presented the award of honour to the cummerbund casuals (arrowed).

● I quote the gist of a letter recently despatched by a British private owner to a certain British airfield, following receipt of an account for a landing fee: "Up to receipt of the account I was not a believer in the supernatural, but I am afraid I must change my views, because the aircraft which made the supposed landing on September —th, although it belongs to me, is still in course of construction, and on the stocks minus engine and minus landing wheels.

"Perhaps you will kindly inform me whether it was Bleriot or Wilbur Wright who carried out this particular flight, in which case I shall get in touch with one or the other through the Spiritualistic Society, as I should like to know how the hell they managed to get the machine out of my workshop without being spotted."

● Last week the technical editor received one of those little plastic/card sliding things which, when you pull the inside in and out, gives you data on something through a series of little windows. This particular example dealt with specifications of ball bearings, but I have seen them for aircraft weight and balance, meteorology, metric conversions and a host of other things.

Wishing to write to the sender, he asked a *Flight* colleague recently returned from the USA, where English is a living language: "What do you call these things?"

The unhesitating reply: *"Portable digital state of the art data-presentation facility incorporating manual linear actuation concept and autovisual read-out capability."*

● I wish I could remember who it was who said or wrote recently that we needn't be too worried about the number of our scientists and engineers who are emigrating.

Needn't we? How about this extract from *Flight's* correspondence page the other week:—

"The strong technical quality of our company [Stanley Aviation Corp, Denver, Colorado] is shown by the fact that, out of an engineering staff of a little more than 100, over 30 of us are British citizens."

● One of the engineer's good old stock entries on a snag sheet is "Fault corrected by cleaning and tightening electrical connection." Well, a story in the Flight Safety Foundation's *Mechanics Bulletin* tells how a new turboprop started to be snagged for high oil temperatures. Twelve temperature thermostats, two valves and two cooler actuator doors were replaced; two cooler actuator doors were re-rigged, and one temperature sensing bulb was replaced. Finally, after 481 hours and 39 crew reports, the snag was found and fixed.

Guess how?

● Extract from Press release:—

"The airliner version . . . has an exclusive removable baggage unit which fits into the rear cabin area like a cork fitting into a bottle and rolls out like a drawer for rapid luggage handling."

This I must see.

● "Sorry, old boy, that's too confidential even to be leaked."

ROGER BACON

DEPLOYING THE DETERRENT

On the Ground
Under the Ground
Under the Sea
On Trains, and
In the Stratosphere

Few things will be more widely dispersed than the deterrent, but its hub (if it has one) is the HQ of Strategic Air Command, near Omaha, Nebraska. This Atlas does not deter

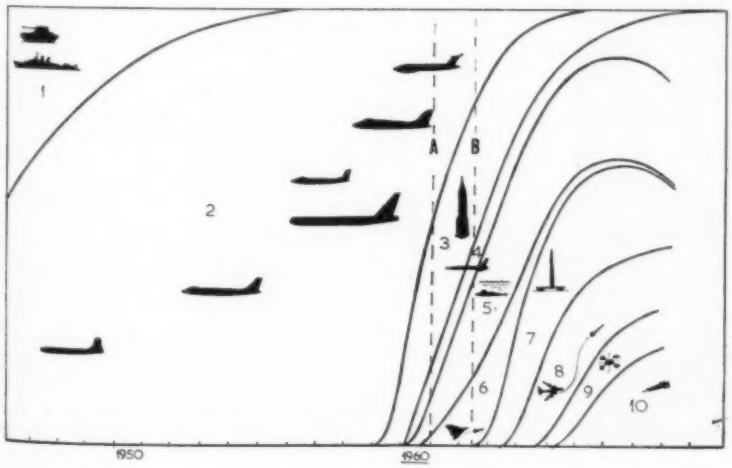
HISTORY contains many examples of a State so powerful that for long periods none dared to attack it. Today the possession of a single thermonuclear weapon, and the means of delivering it, puts any nation—or even a criminally insane gang—into the same exalted position. Inevitably, the members of today's nuclear club have settled down to an uneasy stalemate, based on the concept of deterrence.

Deterrence broadly means "If you hit me, I'll hit you so hard you'll wish you hadn't." It implies the possession of nuclear weapons having an aggregate yield of many megatons, combined with the demonstrated ability to deliver them. There are other terms in the extensive associated jargon which may also require explanation. By *delivery system* is meant the means for transporting the thermonuclear bomb to the enemy target. *Reaction time* is the period which must elapse between the receipt of a signal to mount an attack and the departure of the weapon. A *soft* site is any part of a deterrent system which is vulnerable to nuclear attack, while a *fully hardened* installation is buried in the ground and otherwise protected not only to ensure its *survivability* but also to enable its personnel to operate for an extended period without any form of contact with the outside world. *Degredation* is the modern term for a reduction in the efficiency of a deterrent system, possibly caused by increased vulnerability or reaction time, or by reduced reliability or *penetrative capability*. In Strategic Air Command headquarters, and in many another dark burrow, the word is frequently heard in the catch-phrase "degredation of one's posture." Altogether, the new language would be humorous, were it not horrifying.

Ten years ago the modern concept of deterrence was embryonic. The mushrooming technology of nuclear warheads had as yet produced only one type of device: the fission (U_{235} or Pu_{239}) bomb, derived directly from the huge and crude contrivances which smashed Hiroshima and Nagasaki. By their very weight and bulk, such bombs restricted the number of possible delivery systems; in fact, they could at that time have been transported to a distant, well-defended target only by the piston-engined bombers of the blossoming Strategic Air Command, using a direct extension of World War 2 techniques.

Since that time a whole series of what the Americans call "technological breakthrus" have changed the picture utterly. The ballistic rocket has been perfected as a transport vehicle over global distances, at fantastic speeds, with great reliability and accuracy. Pure inertial systems provide completely self-contained and unjammable guidance. Solid-rocket engines, linked with allied improvements throughout the delivery vehicle, have enabled reaction times to be brought down to a few minutes or even seconds. Most important of all, thermonuclear bombs have been evolved which are a thousand times as powerful as the Hiroshima bomb, yet comparable in bulk with a conventional 2,000-pounder of the last war. Finally, arising from the foregoing, it is now accepted that any delivery system based upon a fixed place of known location is essentially vulnerable.

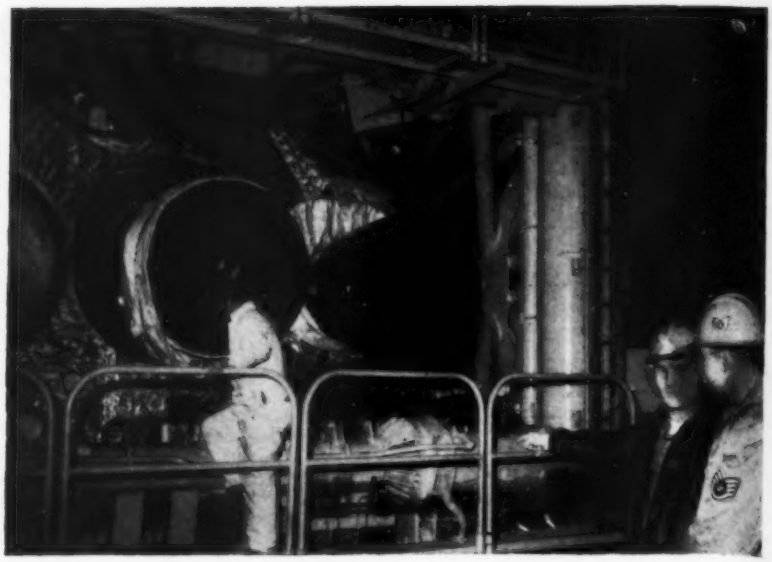
Admittedly, a million fixed-based deterrents, could, by their sheer number, seriously embarrass an enemy; but they would hardly be an economic proposition. To deter, a system must work, and be seen to do so by those against whom it is directed. Weapons



This diagram is an attempt to portray graphically the manner in which the type of armaments most feared by a potential enemy are subject to constant change. At present, for example, the West's deterrent consists of winged missiles launched from aircraft (2 per cent); missiles launched from submarines (5 per cent), cruise-type missiles (1 per cent), ballistic missiles with fixed sites (25 per cent) and manned aircraft (67 per cent). It must be emphasized that the curves are in no sense official, although up to 1965 they should be fairly accurate

1, conventional forces; 2, bombers with free-falling bombs; 3, ballistic missiles from fixed sites; 4, cruise missiles; 5, submarine-launched missiles; 6, bomber-launched cruise missiles; 7, ballistic missiles on mobile launchers; 8, air-launched ballistic missiles; 9, satellites; 10, controllable spacecraft; A, BMEWS warning system operational; and B, Midas/Samos satellite systems operational

DEPLOYING THE DETERRENT . . .



Missilemen of SAC—it would be ludicrous to call them ground crew—have to look after weapon systems of fantastic extent and complication, in which the missile is buried in a mass of ground support equipment. In this photograph engineers of the 564th SMS are about to perform a routine inspection of the propulsion system of an Atlas in an operational emplacement at Warren AFB

which comply with this requirement never do so for long, and nothing that has happened so far suggests that there will ever be an "ultimate weapon," even though one delivery system may for a time seem to be unstoppable. Things which deter probably started with one man having a bigger or a better club than his rivals; and the following list provides a rough framework within which recent deterrents can be examined against a time-scale.

1. Enormous conventional forces—in effect, "men under arms."
2. Aircraft carrying free-falling bombs.
3. Large ballistic rockets launched from fixed emplacements.
4. Strategic cruise-type missiles.
5. Ballistic rockets launched from ships, particularly from submerged submarines.
6. Aircraft used as airborne launching platforms for cruise-type missiles.
7. Ballistic rockets mounted on mobile launchers.
8. Ballistic rockets launched from aircraft.
9. Ballistic re-entry vehicles ejected from a satellite or spacecraft.
10. Ballistic re-entry vehicles launched from controllable hypersonic vehicles above or within the atmosphere.

In the diagram (previous page) it is seen that these ten types of weapons have been introduced in the chronological order in which they are listed. It has been drawn from the viewpoint of what is at present known as "the West," which, from the technological viewpoint, is for all practical purposes synonymous with the United States. The remainder of this essay is basically an amplification of this diagram.

Conventional forces. Until the end of World War 2 the obvious yardstick by which a nation's military strength was measured was the number of men under arms. For some nations, like the United Kingdom, naval strength was particularly important, and in any case sheer numbers could be misleading in a world in which the equipment of a fighting man could vary widely between one country and another. The coming of the nuclear weapon, and a general increase in living standards, rates of pay and many other factors, have all tended to make huge armed forces a deterrent only to the nation burdened with them. Today three men, with degrees in console monitoring and with the right keys round their necks, are more effective.

Here another missileman at Warren takes a look at the GE Mk 3 re-entry vehicle, within which is the thermonuclear bomb

Bomber aircraft. The diagram emphasizes that until the present time the whole burden of delivering the deterrent has rested upon conventional bombers with free-falling bombs. By far the biggest force of such machines is the USAF Strategic Air Command, who have nearly 500 B-52s in service out of a planned total of just over 700. These great aircraft have a range with internal fuel described as "more than 6,000 miles" for the early versions and as "more than 9,000 miles" for the wet-wing G and H models. In service they are supported by several hundred KC-135 tankers, which can refuel them at high speed at their operational altitude. They can carry an assortment of countermeasures, including Quail decoys, and the total yield of their thermonuclear bombs is probably much more than half the aggregate which all Western strategic forces could deliver in the first strike.

Britain's V-bombers are less numerous, but fully competitive in all aspects of performance and operational effectiveness. Great emphasis has recently been placed on establishing the closest possible co-operation between SAC and Bomber Command in enabling the two services to achieve global mobility. Bombers of this calibre need substantial operating platforms, but the coming of jet airliners has ensured that even civil airports will be fully capable in emergency of increasing their dispersal. These strategic bombers may be expected to be used increasingly in independent task forces able to operate for extended periods thousands of miles from their home base. A proportion of the total force can be held on airborne alert, although this is costly over an extended period.

Fixed-base ballistic missiles. In view of the completely new technologies involved, it is surprising that weapons of this type entered service in the West even before strategic pilotless bombers. It is difficult to say exactly when a particular weapon system becomes operational. By the end of 1958 more than one Thor intermediate-range missile was operationally deployed on launchers administered by RAF Bomber Command in East Anglia. In emergency, these missiles could certainly have been launched; but each complex would have been manned by an army of civilians wearing white boiler suits bearing such names as DOUGLAS, ROCKETDYNE, GE or AC SPARK PLUG, and the reaction time might have been more than a day. The first Atlas of the 576 Strategic Missile Squadron in California was in the same semi-operational state in August last year.

Today both the Atlas and Thor are indisputably in operational service. The ICBM can throw a warhead of about 4MT a distance of some 9,000 miles; the IRBM can deliver a slightly smaller warhead within a circle having a radius of a little over 1,700 miles. Both were designed as complete weapon systems before it was appreciated that a fixed, soft site would be as vulnerable as a castle

DEPLOYING THE DETERRENT . . .

made of cardboard. But they were all we had; and, although the United Kingdom—undoubtedly wisely—elected to stop our own fixed-site LRBM programme, the mere fact that Atlas and Thor work and are in service in numbers is considered worth the cost of deployment. Where are they?

Thor is not used operationally by the US Air Force. Instead, it has been installed in England, as this journal described in detail in several issues from December 7, 1958, onwards. Just as the SM-75 Thor missile was a crash programme, so was the rest of its weapon system, and if it had required fully hardened emplacement it is doubtful if the last one for Bomber Command would be even within sight of service. Instead, all 60 missiles are in place, in soft complexes stretching from East Anglia to the Humber. The majority are on RAF airfields, and, although it would be a breach of security regulations to draw a map showing where they are, anybody with means of transport could very soon find out—he could, for example, join the nearest procession of Nuclear Disarmament protest marchers and see where they went. Seriously, the five complexes have all been named publicly, and each administers four squadrons with three missiles apiece. Mean distance between squadrons may be from 10 to 25 miles. The whole idea is to spread the Thors uniformly, so that no nuclear bomb, or even half a dozen, could cripple the whole force.

At this point one cannot delay any longer stressing the importance of receiving adequate warning. Especially if one's delivery system is soft, it is literally vital to know of an impending enemy attack; because, if one's own deterrent can be caught napping and destroyed in the middle of its countdown, it ceases to deter. The ballistic-missile early-warning system, or BMEWS, at present involves huge detection radars at Thule, Greenland, and at Clear, Alaska, plus tracking radars at Fylingdales, Yorkshire. The detection radars spot an enemy ballistic missile rising, perhaps 3,500 miles away, as it comes above the horizon. The tracking dishes lock-on to it and compute its exact trajectory, impact point and time of arrival. Then a lot of automatic circuits are triggered, a lot of telephones ring and the deterrent has failed. (After all, and many pacifists entirely miss this point, the whole idea of the deterrent is that nobody must ever need to use any of it.)

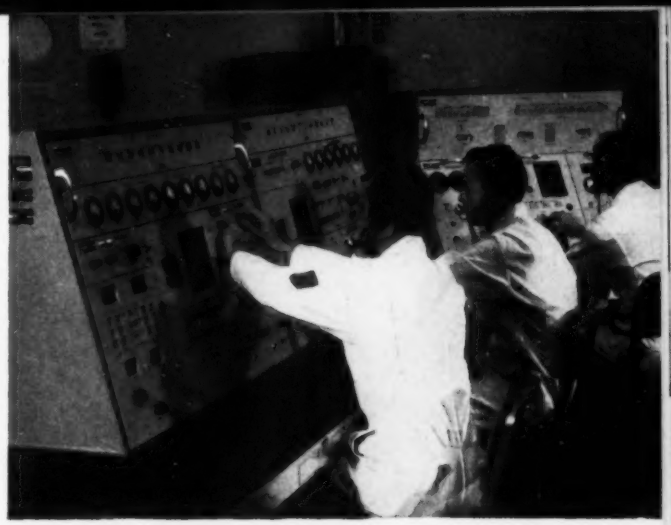
Without BMEWS the British Thors, with their 15-min countdown, would seem to be sitting ducks. With it, they still seem to be sitting ducks; but not all of them could be knocked out at once (it says here) and so they can legitimately be classed as a deterrent. If our Thors need BMEWS, so do the Atlases of Strategic Air Command. An accompanying map, reproduced from the excellent newspaper published by the USAF Ballistic Missile Division, shows where they are to be found. America is so big that our spy who searched for the Thors in England would die of old age long before he had found half the Atlases, so the Department of Defense conveniently sanction publication of all the details.

Notes on the Atlas squadrons and their emplacements will be found in the review of the world's missiles a few pages further on. The soft complexes are just bigger editions of the RAF Thor sites, except for the fact that high-pressure gaseous helium is used to force the hundred tons of propellants into each missile, instead of nitrogen (which is easier to come by outside the US). It is too early yet to assess exactly what proportion of the missiles in SAC hands will, at any given moment, be able to start a countdown, but it would be surprising if the figure were far removed from 75 per cent. As for reaction time, this is nominally 15min, but any given missile can be counted down to T minus 8 (eight minutes from lift-off), or just before the liquid oxygen starts to flow, and held there for a long time. And if BMEWS cannot give places like Warren and Offutt AFBs more than eight minutes' warning somebody had better go back to the think tank.*

Not all the Atlases will have to be soft. At three bases the missiles will be stored flush with the ground, although the degree of hardening which this confers is meagre. In contrast, the final six squadrons will be fully hardened, the missiles being stored vertically in silos 52 to 54ft in diameter and 170 to 175ft deep. An accompanying diagram also shows that the only supporting installation is a single underground blockhouse, containing living quarters and the launch consoles. The diagram gives no indication of the location of the propellant storage, and the absence of ground guidance facilities confirms that the hard Atlases will have the all-inertial system.

After much research Convair found that it would not be possible to launch the Atlas from the bottom of the silo, since the missile airframe and systems could not survive the inferno of flame which would shoot up around it and roar through the overhead doors while the missile was still extricating itself from the hold-down clamps. Accordingly the missile rests on a flame-deflector bucket mounted on a crib which is hoisted to the surface at an advanced stage in the countdown. The sketch indicates the multi-storey work platforms around the missile, and the fact that counterweights are located on at least two sides of the internal structure.

**This is not deterrent jargon, but US aircraft-industry jargon. For proof, see "Straight and Level" for January 1 last.*



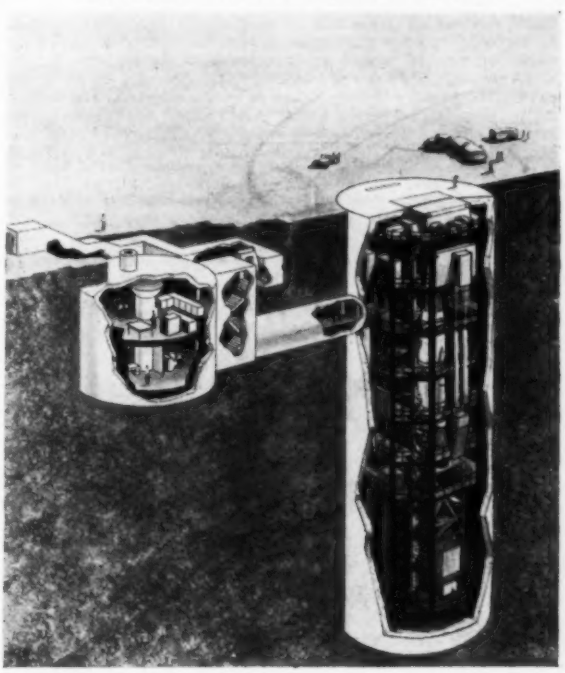
These missilemen are not models posing with a mock-up, but enlisted men of the USAF at live Atlas checkout consoles

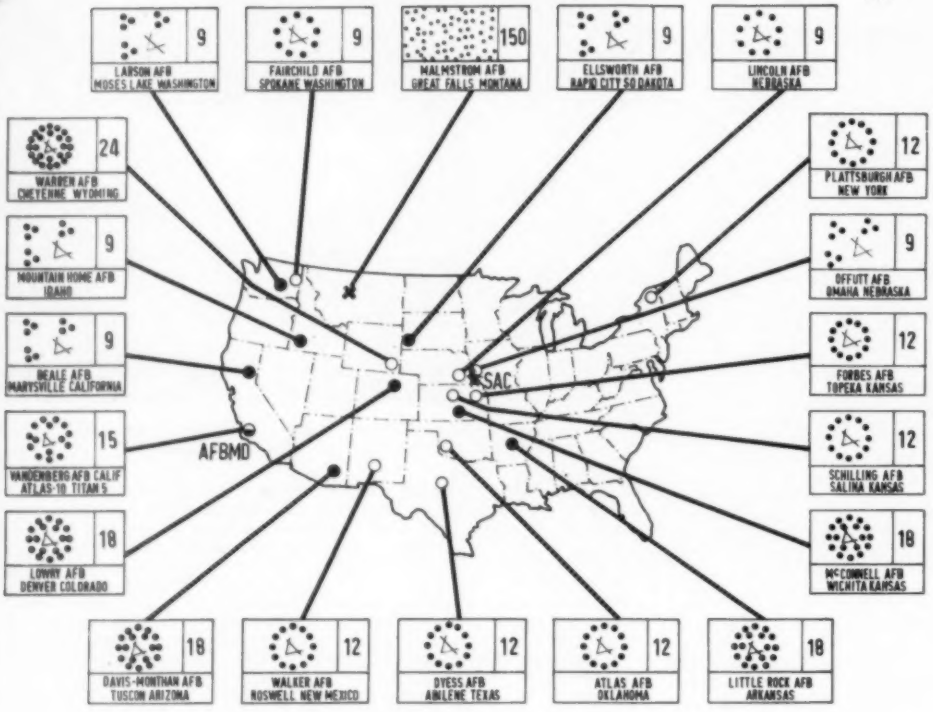
Contract for detailed design and fabrication of the underground launch systems was placed with American Machine & Foundry Co, who are now engaged in such major aspects as the crib suspension, launch-platform drives, blast doors and hydraulic power packages. It has been found that the most economical way of protecting the missile against the shock of a nuclear blast is to suspend the crib on shock-absorbing mountings. In view of the earth movements involved these must permit vibrations with an amplitude of at least a foot. What is more, the structure inside the silo must remain dimensionally accurate, so that nothing jams as the missile is elevated.

These troglodytic tendencies lead one naturally to SAC's second ICBM, the Titan. Of this, Martin's Denver Division (who make it) say, "The Titan, in its underground fortress, can be lifted to the surface and fired during the few minutes after any enemy missile has been launched and before it strikes. Or if there is no warning, the Titan hard base can withstand a near miss of a nuclear bomb. Even though the surface of the land is seared, the giants in the earth still could deliver their answering megatons of death." Not every company can talk about its products like this.

As described in the review of Titan on a later page, a total of 12 squadrons has been announced. Each will consist of three complexes of the type illustrated, and each complex contains three missile silos. As in the case of Atlas, Titan 1 has to be hoisted to the surface before launch, but Titan 2 will not only have storable

The final six Atlas squadrons will each have 12 missiles in individual fully hardened silos protected against enemy attack





A map of the continental United States, showing the location and strength of the ICBM bases of Strategic Air Command which have so far been announced. Atlas bases are represented by white circles, Titan bases by black discs and the first Minuteman base by an X. The Titan 1 bases show the three triple complexes of each squadron quite accurately, except for Lowry where the 18 missiles of the two squadrons are suggested by concentric circles. The circular arrangements are really only schematic; particularly is this the case with Warren, which has three Atlas squadrons deployed in a haphazard arrangement

DEPLOYING THE DETERRENT . . .

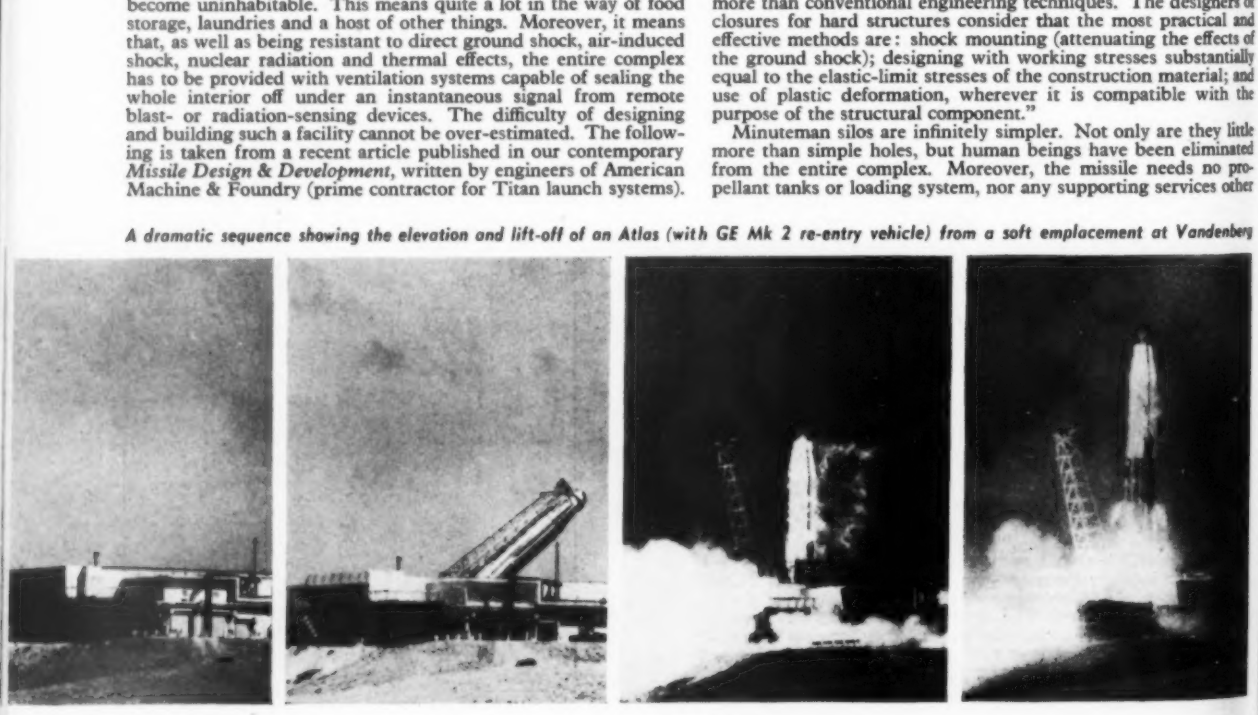
propellants but will also be fired from the bottom of its silo. As for the rest of the complex, the best one can do is invite the reader to study the pictures, assisted by the following statistics: earthwork, 700,000 cu yd of open-cut excavation, the earth being replaced over the completed complex; concrete 96,000 cu yd, "enough for 510 miles of sidewalk"; steel, 24,000 tons, "enough to build 13 destroyers"; power, continuous generation of 4,000kW; water storage, 60,000gal, replenished from wells on the site.

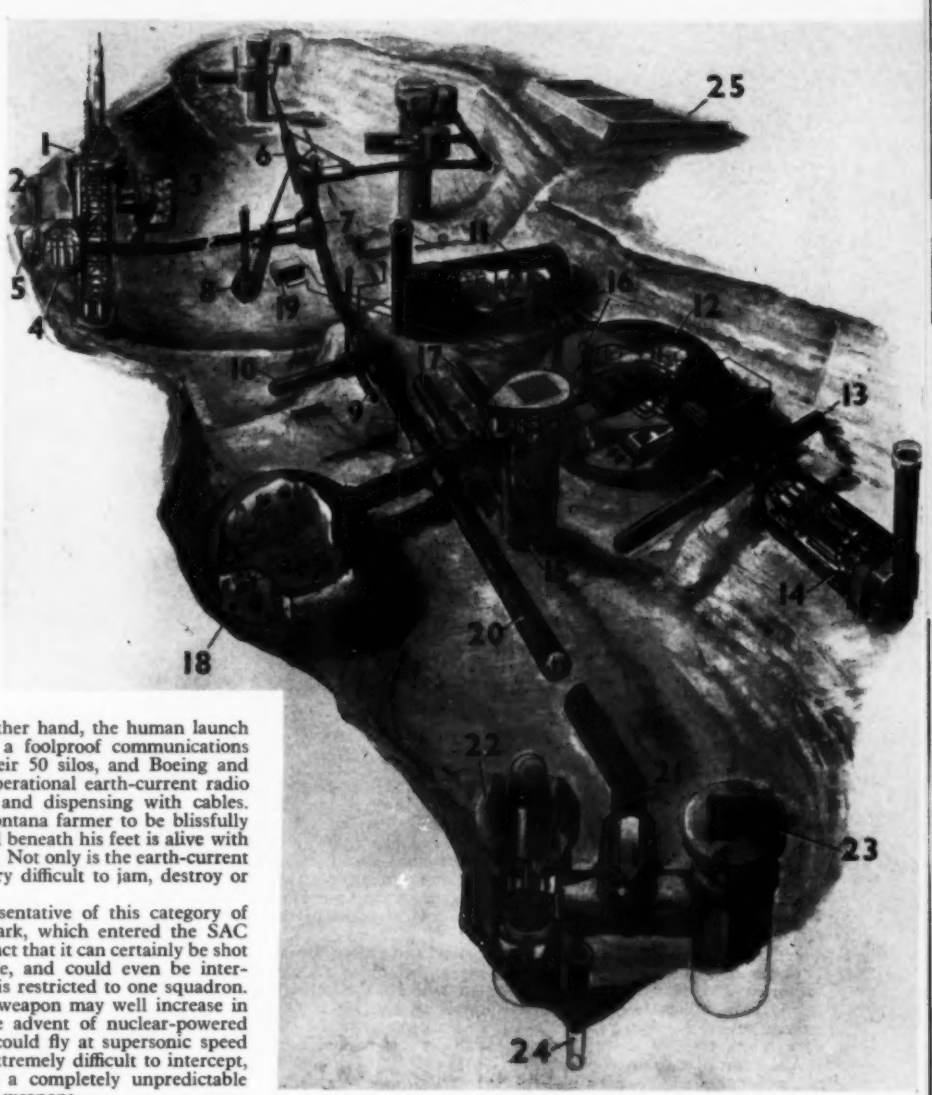
Nor is this all. The 200 men in each complex must not only live there but be able to go on doing so long after the terrain above has become uninhabitable. This means quite a lot in the way of food storage, laundries and a host of other things. Moreover, it means that, as well as being resistant to direct ground shock, air-induced shock, nuclear radiation and thermal effects, the entire complex has to be provided with ventilation systems capable of sealing the whole interior off under an instantaneous signal from remote blast- or radiation-sensing devices. The difficulty of designing and building such a facility cannot be over-estimated. The following is taken from a recent article published in our contemporary *Missile Design & Development*, written by engineers of American Machine & Foundry (prime contractor for Titan launch systems).

"A simple illustration will serve to show the magnitude of the loads encountered. Consider a door which is perpendicular to the direction of the blast wave . . . The overpressure multiplication factor at a 90° angle is 3. Assuming that the area of the door is 20ft × 20ft and the level of overpressure is 100lb/sq in, the load caused by air blast equals 300lb/sq in, or a total of 17 million pounds. Using as an example a reinforced concrete door 4ft thick × 24ft square, and assuming it to be subject to 50g horizontal acceleration, the total force caused by ground shock would be fifty times the weight of 2,300 cu ft of concrete (at 150lb/cu ft), again a total of approximately 17 million pounds. From the simple calculations, it can be seen that forces of such magnitude require more than conventional engineering techniques. The designers of closures for hard structures consider that the most practical and effective methods are: shock mounting (attenuating the effects of the ground shock); designing with working stresses substantially equal to the elastic-limit stresses of the construction material; and use of plastic deformation, wherever it is compatible with the purpose of the structural component."

Minuteman silos are infinitely simpler. Not only are they little more than simple holes, but human beings have been eliminated from the entire complex. Moreover, the missile needs no propellant tanks or loading system, nor any supporting services other

A dramatic sequence showing the elevation and lift-off of an Atlas (with GE Mk 2 re-entry vehicle) from a soft emplacement at Vandenberg





A typical Titan complex, three of which form a complete squadron armed with nine missiles (plus one in reserve). During base construction the ground is excavated to a depth of about 160ft; the complex is then erected on the new ground-level, after which the earth is put back

1, liquid-oxygen filling and venting; 2, launch silo; 3, equipment terminal; 4, propellant terminal; 5, liquid-oxygen tank; 6, blast lock to two missiles; 7, blast lock to third missile; 8, launcher-area air-filtration facility; 9, nitrogen tank; 10, missile fuel tank; 11, powerhouse air-filtration facility; 12, diesel-electric powerhouse; 13, diesel-oil tanks; 14, powerhouse exhaust facility; 15, portal (main entrance); 16, TV camera and instrument mounts; 17, water storage tanks; 18, control centre; 19, chemical-waste clarifier; 20, personnel tunnel; 21, guidance antenna terminal; 22, antenna No 1; 23, antenna No 2; 24, exhaust vent; 25, sewage stabilization

than a checkout console. On the other hand, the human launch crew at squadron HQ must have a foolproof communications system linking them to each of their 50 silos, and Boeing and Sylvania are developing the first operational earth-current radio network employing buried aerials and dispensing with cables. Shortly it will be possible for a Montana farmer to be blissfully unaware of the fact that the very soil beneath his feet is alive with SAC crews "talking" to Minutemen. Not only is the earth-current system cheap but it will also be very difficult to jam, destroy or sabotage.

Cruise-type missiles. Sole representative of this category of weapons is Northrop's graceful Snark, which entered the SAC inventory a year ago. Owing to the fact that it can certainly be shot down by a ground-launched missile, and could even be intercepted by a fighter, its deployment is restricted to one squadron. Yet round about 1966 this class of weapon may well increase in importance (see diagram), with the advent of nuclear-powered vehicles of great endurance which could fly at supersonic speed very close to the earth's surface. Extremely difficult to intercept, they could range far and wide in a completely unpredictable manner, carrying any of a variety of weapons.

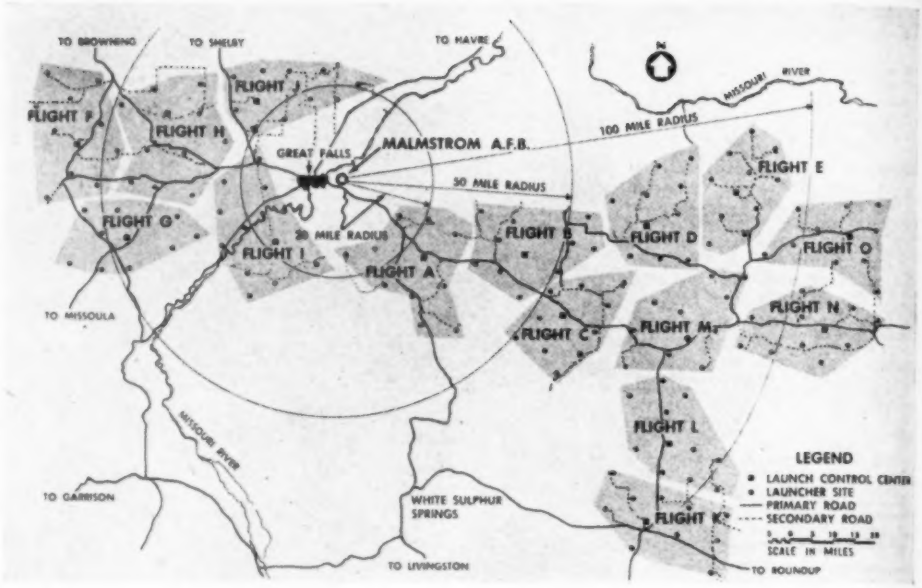
Submarine-launched missiles. Whatever the US Air Force and a number of "have not" nations may claim, there seems little reason to doubt the belief of the US Navy that a modern submarine is not very vulnerable. Particularly is this the case with the Fleet Ballistic Missile Submarines, which do not have to chase enemy ships but can lie at rest for months on end without making a sound. It is a remarkable fact that the incredible series of difficulties and uncertainties posed by the concept of a submarine-launched ballistic missile appear all to have been solved—and to a brief time-scale. Almost the only disadvantage of this delivery system is that its first stage weighs 8,600 tons and costs about £40m.

Nevertheless, this first stage is at least intended to be reusable. Operationally the US Navy's eventual fleet of 45, carrying 720 Polaris missiles, could undoubtedly threaten every point on the earth's surface simultaneously, even allowing for the proportion which at any time would be in port for overhaul, victualling and (every twenty million miles or so) refuelling.

Air-launched missiles. Discounting the defunct Rascal, the first strategic weapons in this category are Hound Dog and Blue Steel. The former is now well into squadron service with SAC, and 11 of that command's bomber bases have already been named as recipients. Although the missile is only just supersonic by modern standards (about M1.6), its operational versatility, ability

Any fully hardened complex must be self-sufficient in every respect. To meet all power requirements in a Titan triple complex, a generation plant (item 12 above) generates 4,000 kilowatts (left). Right, a Titan and its umbilical mast slowly emerge from between the 200-ton doors of a silo at Vandenberg AFB; the second stage has completely emerged and the weapon will lift off in a very few minutes

DEPLOYING THE DETERRENT...



Taken from our American contemporary "Missiles and Rockets," this map of the area south and east of Great Falls, Montana, illustrates the disposition of the 150 Minuteman missiles of the three squadrons based at Malmstrom. The lonely 2-acre plots will be divided into 15 Flights, each with a launch-control centre. Base construction will start at the end of the year and will be finished at Flights A and B within seven months

to conduct violent programmed manœuvres and large payload make it quite attractive against even well-defended targets. Accuracy is certainly no problem, and test missiles fired from B-52s seem to have impacted within a mile of their target location. Britain's Blue Steel is a rocket-propelled weapon, from which one could deduce that it may have a rather higher performance than Hound Dog (especially at extreme altitude) at the expense of shorter range. Another characteristic is that the Victor and Vulcan bombers are designed to carry a single Blue Steel, whereas SAC's B-52s can carry a Hound Dog under each wing. It is generally felt that missiles of this character, while conferring a valuable increase in penetrative ability upon existing bombers, will not be able to live in the defensive environments of the second half of this decade.

Missiles on mobile launchers. Most tactical and army weapons have for many years fallen into this category. From the strategic viewpoint the first such weapon system will be the railroad Minuteman, which may become operational in late 1962. Disadvantages of the system are few. A Minuteman train could at once be spotted by any trained eye, and under certain conditions would seem to be rather vulnerable to sabotage, but one can be quite sure that SAC is thinking hard of every possible eventuality, and introducing appropriate countermeasures. The model launch car in the photograph is actually of an interim design, but it differs from the operational vehicle only in details. Nothing has yet been divulged regarding the navigation system which these trains will employ, but for the best overall mission accuracy it would be logical to fire only from sidings which had been specially surveyed in advance, to ensure that the position of the launch car was known as accurately as the position of, say, each Atlas launcher.

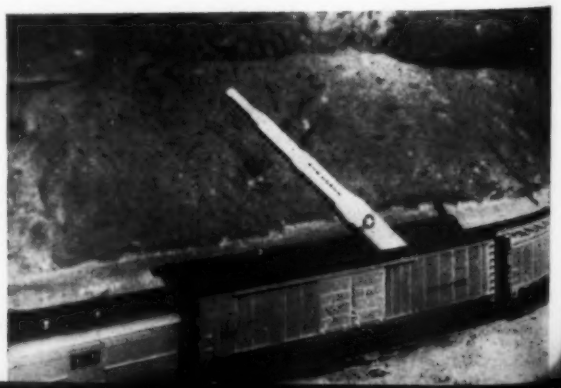
Air-launched ballistic missiles. The enthusiasm of SAC for the ALBM is understandable, for it provides superb mobility, dispersal and overall effectiveness far greater than anything which can be achieved by a fixed-base missile, yet involves only modest research and development expenditure, hardware procurement or crew training. Similarly, the British Minister of Defence is all-agog to buy it for Bomber Command. In this case the enthusiasm stems also from the simple fact that no other British deterrent is in prospect. Countermeasures could be numerous. Any anti-ICBM system could also detect, track and destroy the re-entry vehicle from an ALBM. The bomber carrying it could be shot down, or even destroyed at its home base. These things are accepted; but Skybolt is still an excellent investment. In fact, there have been strong hints that the United Kingdom is going to try to do a junior partner for it.

Satellites. Much has been made in newspapers of horrifying "bomb satellites." The original sketch of deterrent systems does, in fact, include such devices; but the cold truth is that they do not seem to be a very good idea. In effect a satellite is a mobile base from which a re-entry vehicle can be launched. Admittedly, a satellite could be provided with a propulsion system capable of being started and stopped in space in order to modify the orbit considerably, but the fact remains that a satellite should be a very simple thing to intercept. Perhaps the US Army could start by investigating whether a Nike Zeus could destroy Echo 1. (But satellites can perform essential reconnaissance and early-warning functions.)

Controllable spacecraft. Much more attractive than simple orbital vehicles, this class of aerodynes—which may variously function as hypersonic gliders, skip vehicles alternately entering and departing from the upper reaches of the atmosphere, or pure re-entry vehicles which can be steered through the atmosphere—appear to offer entirely new military possibilities. They may well be a prerequisite to the military use of space, and from the viewpoint of warhead delivery they offer the ultimate in penetrative ability and accuracy. Unlike the re-entry vehicle of an ICBM, the trajectory of a hypersonic aerodynamic device need not be ballistic. It could perform considerable changes in direction, and, when the formidable problems of heating and acceleration have been overcome, might be able to manœuvre like an ordinary aeroplane. Sole representative of this class is Dyna-Soar, which is scheduled to be boosted into space by a Titan in about three years' time. No military mission has been associated with Dyna-Soar, but finding tasks for such a vehicle to perform should be the least of its problems.

W. T. G.

The second-generation Minuteman will be deployed either as a fully mobile weapon system or as a dispersed and fully hardened one. In the latter form it will be transported and lowered into its silos by the vehicle on the left; the railway Minuteman is depicted in model form



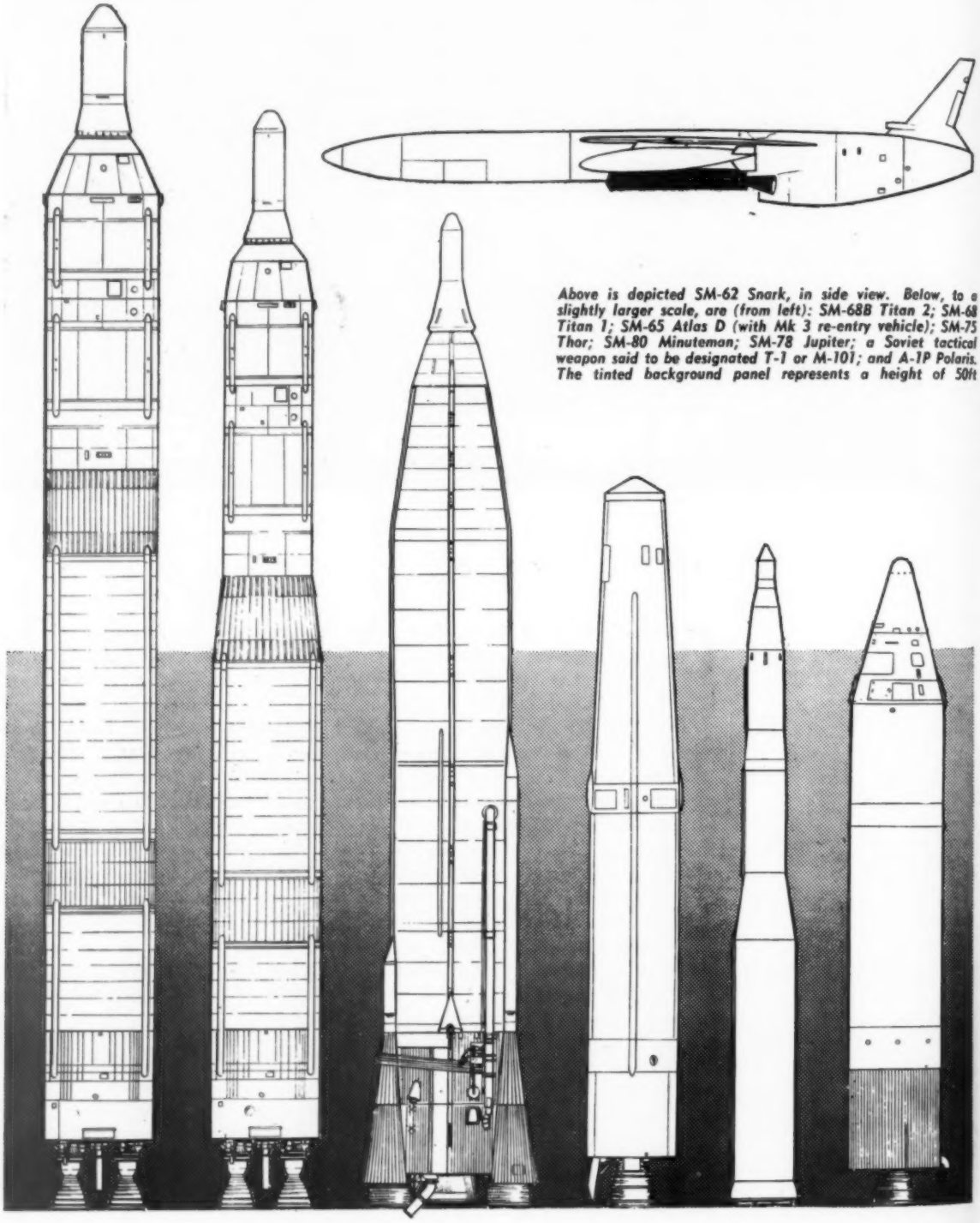
Missiles 1960

ON this page we open our fifth annual review of the world's guided missiles, written, like its predecessors, by the Technical Editor. As the field to be covered has expanded, so has the treatment necessarily become more selective; and this year some weapons of lesser significance are perforce dismissed by a note bidding the reader to seek further information in earlier reviews. These were published on December 7, 1956; December 6, 1957; December 5, 1958; and November 6, 1959. In certain cases reference is also made to issues in which have appeared descriptions of individual missiles or emplacements, frequently with detailed cutaway drawings (of which we have published many more than any other journal). Such selectivity has been necessary in order that maximum space may be devoted to those guided-weapon systems which are truly of the first order of importance. Even so, these mighty "systems"—they are much more than just the delivery vehicle—are so vast in extent, and so completely new, that our 3,000 words on Minuteman, for example, could be said barely to scratch the surface.

Only military devices are recorded in this review; peaceful space aspirants have their place in another special issue which can hardly fail to become an annual one. In some cases the present review admits missiles which do not possess an internal guidance system (or, in one case, a missile with guidance but devoid of an internal powerplant). The borderline between (a) things which are more properly classed with artillery shells or torpedoes, and (b) those which are unquestionably *Flight's* concern is a nebulous one. This year, for example, we have seen fit to accord more than a passing glance at anti-submarine systems; hardly appropriate for an aviation journal, it may be argued, yet done advisedly in view of the immense importance of ASW operations both to flying men and to the missile makers. Another change is that data on each class of missile have been collated in tabular form.

Strategic Missiles

Propellant abbreviations used in the tables in the following pages are: LO_2, liquid oxygen; K, kerosine; PBAA, polybutadiene acrylic acid; PU, polyurethane; RFNA, red fuming nitric acid; HTP, high-test peroxide; RP-1, wide cut paraffin; N_2O_4, nitrogen tetroxide; JP-4, gas-turbine wide-cut fuel; UDMH, unsymmetrical dimethyl hydrazine; H, hydrazine; AP, ammonium perchlorate.



Above is depicted SM-62 Snark, in side view. Below, to a slightly larger scale, are (from left): SM-68B Titan 2; SM-68 Titan 1; SM-65 Atlas D (with Mk 3 re-entry vehicle); SM-75 Thor; SM-80 Minuteman; SM-78 Jupiter; a Soviet tactical weapon said to be designated T-1 or M-101; and A-1P Polaris. The tinted background panel represents a height of 50ft

Atlas

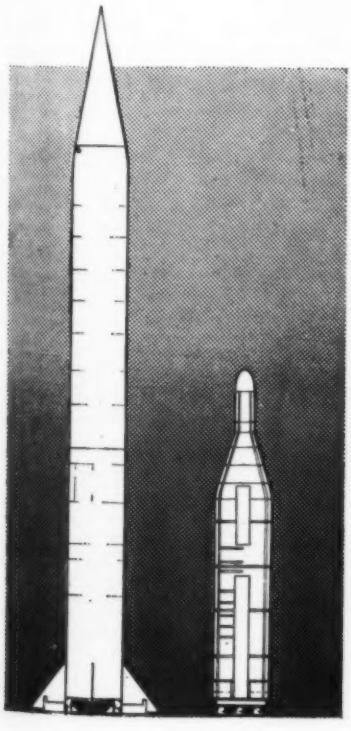
ICBM for deployment from fixed bases

US AIR FORCE

IN last year's review we wrote "outside the Soviet Union, the USAF Weapon System 107A-1, of which the Atlas missile forms a part, is the only ICBM system to have reached the operational stage"; and this is still the case. Although Convair's first research and development contract for a long-range ballistic missile was awarded as early as 1946, state-of-the-art advances in all aspects of the concept, particularly in warhead yield per unit weight, delayed progress for nine years, and the go-ahead on WS-107A-1 was not received until January 1955. Captive testing began the following year and the first Atlas flew in June 1957. The first full-range flight took place in November 1958, the first launch by a Strategic Air Command crew using operational ground-support equipment came in September 1959, and at the time of writing there have been 70 launches, 51 of them wholly or mainly successful.

Features of revolutionary character were evolved by Convair Division of General Dynamics in their role as prime contractor. These include the pure-monocoque construction of the tankage sections from extremely thin stainless-steel sheet, the completed assembly being pressurized to approximately 10lb/sq in to maintain stability. At the lower end the tankage section is attached to a corrugated booster section containing a pair of Rocketdyne LR105 engines with gimballed chambers. Between these engines is the Rocketdyne LR89 sustainer, with a single chamber gimballed to the conical base of the fuel tank. On either side of this tank is hung a small vernier motor to provide close control of the final trajectory. All five engines are fired on the ground; the boosters are jettisoned after approximately two minutes, and powered flight continues for a further three minutes when firing on a full-range trajectory.

After vernier shutdown, the nosecone and re-entry vehicle are separated from the remainder of the airframe and the latter is pulled back by small retro-rockets. The ballistic trajectory lasts approximately a further 30min and reaches an apogee of some 800 miles. Finally the missile and nosecone (by now several miles apart) re-enter the atmosphere, encountering conditions which only the re-entry vehicle can survive. The first type of re-entry vehicle flown on the Atlas was the General Electric Mk 2, with a heavy copper heat-sink impacting subsonically. The operational version is the same company's Mk 3 ablative pattern, which reduces the weight and greatly improves both accuracy and impact velocity. The Avco RVX-4 has also flown on Atlas, and the big Mk 4 cone may become an operational alternative to the Mk 3.



Initially Atlas was designed to use a radio/inertial guidance system, the missile's trajectory being plotted by powerful GE ground radars and their measurements being translated into corrective signals by a Burroughs computer. Although this system has been employed on most of the missiles so far launched, it was decided two years ago to transfer it to the first series of Titans in exchange for the latter missile's pure-inertial guidance by American Bosch Arma.

Production of Atlas is now at the maximum programmed rate at the *ad hoc* Convair Astronautics plant north of San Diego. During the first 30 months of Atlas manufacture all missiles were delivered on trailer/erectors built by Goodyear Aircraft, but since November 1959 deliveries have been accomplished by Douglas C-133Bs. The first Strategic Air Command Atlas base is at Vandenberg AFB, home of the 1st Missile Division. This is the operational training base for all ICBMs and is the headquarters of three squadrons, one for each type of ICBM. The Atlas squadron is the 576th Strategic Missile Squadron, who fired their first missile on September 9, 1959.

All the missiles deployed by the 576th SMS at Vandenberg are in soft (above-ground) emplacements which are direct refinements of the original research and development installations constructed at Cape Canaveral. The first purely operational Atlas base is Warren AFB, where three Atlas squadrons will occupy sites within a radius of 50 miles of Cheyenne, Wyoming. The 564th SMS occupy six soft emplacements with end-sliding roofs all arranged in a single complex. The 565th SMS are occupying three complexes each containing three missiles in soft emplacements with split roofs sliding sideways (slightly reducing the erection time). The 549th SMS will have nine missiles, each in a completely isolated semi-hard installation in which the missile lies horizontally below ground level until erection.

A total of 13 operational Atlas squadrons has been announced; the three already mentioned, and one each at Vandenberg, Offutt, Fairchild, Forbes, Schilling, Lincoln, Altus, Dyess, Walker and Plattsburgh. Training facilities are being activated at Sheppard and Chanute AFBs. Of the 13 squadrons, the first seven (three at Warren, and Vandenberg, Offutt, Fairchild and Forbes) will be soft or semi-hardened. The remaining six will be fully hardened emplacements housing the missile vertically in a silo 175ft deep and 52ft in diameter. The missiles will be suspended in shock-absorbing cradles, this having been found to provide maximum protection against nearby nuclear explosions. Elevators will raise the missiles to the surface during the countdown. Each of these fully hardened installations will have 12 launchers instead of the standard nine, under an expansion programme approved last April. Bearing in mind that the first Warren squadron has only six missiles, this means a total of 132 operational Atlas ICBMs, all of which should be emplaced within 18 months. The total number at present on launchers is about 15, and labour trouble has put base-construction a little behind schedule.

Important flights since our 1959 review include the following: January 26, missile 6D, successful 4,500-mile flight by SAC crew from Vandenberg; same day, 44D, successful 5,000-mile flight carrying Avco RVX-4 re-entry vehicle; February 26, 29D, launch of first Midas infra-red surveillance satellite; March 8, 42D, full-range flight with all-inertial guidance on open loop; May 20, 56D, successful flight of 9,040 miles to impact area in Indian Ocean (this missile was identical in power to other series-D Atlases and demonstrated a range capability realized by re-programming the flight path; it carried an operational nosecone, which was not recovered, and 1,000lb of test instrumentation which would not be present in an operational missile); May 24, 45D, successful launch of Midas satellite; June 11, 54D, successful full-range flight controlled by inertial system; October 11, 3E, first launch of advanced operational series. The E series have increased power resulting from the improved MA-3 propulsion system, giving an operational range of up to 10,000 miles with full payload. It is the first production variant with inertial guidance, and will equip all operational squadrons except for the 576th and 564th.

Atlas provides booster power for the Midas and Samos USAF satellite systems, which are respectively to provide infra-red and photographic surveillance. The missile also forms the first stage of Mercury (man-in-space) and the high-energy Centaur, as well as having been responsible for many space shots, mated with Able or Agena second stages.

Blue Streak

THIS ballistic missile was intended for deployment by RAF Bomber Command in fixed, hardened silos. Having a design range of about 2,500 n.m., it was a straightforward concept managed by D.H. Propellers, with a stainless-steel balloon-type airframe made by D.H. Aircraft (assisted by Convair), twin LO_2/kerosine engines by Rolls-Royce (assisted by Rocketdyne), inertial guidance by Sperry and fired from a Morfax launcher rotating in azimuth. The contract was cancelled in April of this year, about a year from first flight, when total R and D costs had amounted to about £65m.

French I R B M

FOR more than two years France has been assiduously perfecting her own nuclear weapons, and, although she is as yet a long way even from having one which could be put inside a missile, she is striving to develop delivery systems involving both manned bombers and ballistic missiles. The former is the Mirage 4. The latter is to be a solid-propellant intermediate-range weapon which may be expected to learn all it can from such advanced American missiles as Polaris, Pershing and Minuteman. The programme is being managed by an *ad hoc* consortium named Sereb (Soc d'Etudes et de Réalisation d'Engins Ballistiques), which embraces both government establishments and industry.

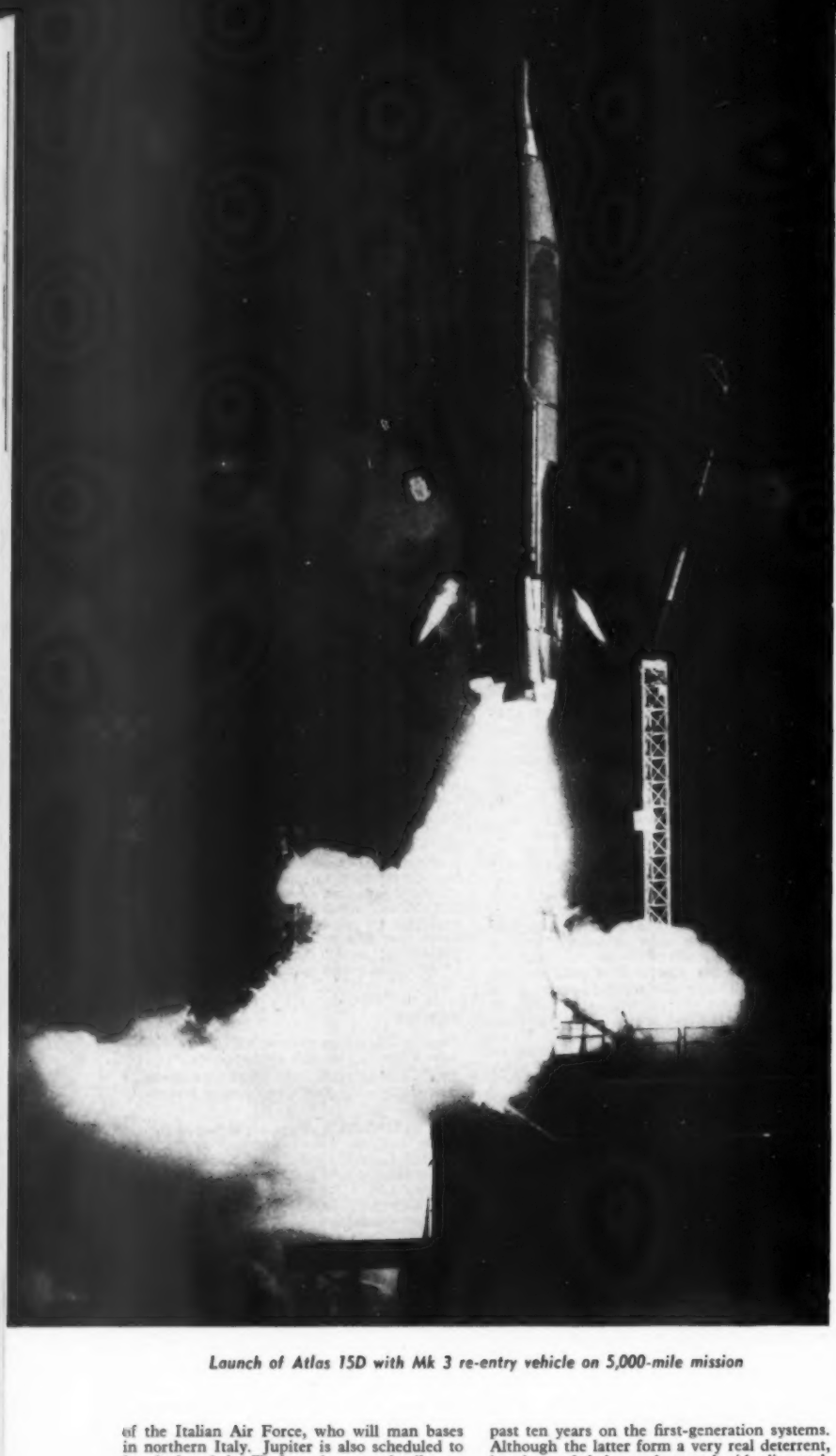
Jupiter

Intermediate-range ballistic missile for deployment from mobile, soft emplacements

US AIR FORCE; SCHEDULED FOR DEPLOYMENT BY THE ITALIAN AIR FORCE AND ARMED FORCES OF TURKEY

DEVELOPMENT of Jupiter began at the US Army Ballistic Missile Agency at Redstone Arsenal early in 1956. Its clouded political background will be found outlined in our 1958 review, and a full description in our 1959 review (pages 511-2). Its concept could hardly be more straightforward. The propulsive section is a pure cylinder, fabricated from aluminium alloy, the tail having axial corrugations to increase stiffness. The engine is a Rocketdyne S-3D, and the turbopump exhaust is piped outboard to a swivelling nozzle to provide roll control. The inertial guidance system, by ABMA and Ford Instrument, is mounted in the aft section of the nose, where it governs the trajectory after separation from the main body by controlling a solid vernier motor. When the correct trajectory has been achieved explosive bolts separate the warhead and ablative nosecone.

Jupiter entered the flight-test stage on March 1, 1957, and the final research and development launch took place on February 4 last. A total of 29 missiles flew during the programme, and four were launched as space boosters with the designation Juno 2. Operational control of Jupiter was transferred by the Secretary of Defense to the USAF Strategic Air Command. Early in 1958 the 864th Strategic Missile Squadron was activated at Redstone Arsenal, and is now an operational unit capable of being deployed overseas (since the missile does not require a fixed base). Nothing has been heard of the 856th or 866th, also announced in 1958 as Jupiter units. Redstone has for some months been training units



Launch of Atlas 15D with Mk 3 re-entry vehicle on 5,000-mile mission

of the Italian Air Force, who will man bases in northern Italy. Jupiter is also scheduled to be deployed in Turkey, but no details are forthcoming.

Minuteman

ICBM for deployment from fixed hardened silos or from railway trains

US AIR FORCE

SOLE second-generation ICBM in the West, Minuteman is also the West's largest weapon programme, from the viewpoints of either effort or cost. Its technical excellence and operational attractiveness are the reward for the dollars, sweat and tears expended over the past ten years on the first-generation systems. Although the latter form a very real deterrent, by virtue of their numbers and wide dispersal, they suffer from the handicaps which caused Britain to cancel her own first-generation weapon Blue Streak: the inherent vulnerability of a fixed site, coupled with long reaction time and enormous cost. During 1957 it was painfully apparent to the far-sighted engineers at the AFBMD that the first-generation weapons were far from being optimum delivery systems. It was felt that "there must be an easier way"; and this has now become an accomplished fact with the development of the second-generation Minuteman.

This easier way rests upon state-of-the-art

advances in all portions of the weapon system. Progress in the miniaturization of thermonuclear warheads and inertial guidance systems did not cease when these portions of the first-generation weapons were "frozen" for production, and this has been instrumental in slashing the weight of the complete missile to roughly one-quarter that of its predecessors. The most important single advance results from the use of solid rocket propellant, and, by choosing ambitious design targets in such matters as specific impulse, mass ratio and case design, it was possible to evolve an optimized three-stage vehicle far surpassing in size and performance anything previously attempted with solid propulsion. At one stroke, solid propulsion reduced reaction time from around 15min to as many seconds; it probably improved reliability to a considerable degree, and certainly reduced both the capital and maintenance costs of the complete weapon system very substantially. At the same time, the reduced bulk and complexity of the weapon system have made it far more amenable to dispersed emplacement in silos or on board special trains.

Work on the Minuteman system really began with the establishment in 1955 of a special ARDC office to study the problems of producing a solid-propellant ICBM. It was soon determined that the greatest areas of uncertainty —propellant manufacture, fabrication of the rocket cases and methods of thrust vector control—posed no insuperable problems, and by the end of 1957 the Minuteman was a firm programme. Initially it was felt that it might be possible to employ the weapon as a three-stage, two-stage or single-stage delivery system, but in the event it was decided to go for the single prime mission of a 5,500n.m. ICBM at instant readiness, employing all three stages.

Development since that time has been the largest single task under the management of AFBMD (systems engineering and technical direction by STL), and the overall programme has been funded as required. Prime contractors for assembly and test, guidance, propulsion and the re-entry vehicle are associates of roughly equal standing, but the firm responsible for assembly and test—The Aero-Space Division of Boeing Airplane Co—is regarded as the industrial manager. Last July Boeing received a letter contract for $247m to cover their R & D expenses until the end of December 1961.

Minuteman cannot really be said to have an airframe, in the sense in which the word is normally used. Instead, the re-entry vehicle is placed in its trajectory by a propulsion system consisting of first, second and third stages each virtually a simple drum, filled with solid fuel, which drops off after burnout. But there is more to it than that. Case fabrication has been farmed out to at least seven companies; at the time of writing it appears that all three stages employ wrapped and welded steels of very high strength.

The first stage is the largest solid rocket ever put into production, and Thiokol's Wasatch Division make it at a special facility in Utah, for the expansion of which $17m were voted six weeks ago. The propellant is a mix of polybutadiene acrylic acid plus an ammonium perchlorate oxidant, with a Thiokol binder and a small proportion of an aluminium-based additive to ensure smooth combustion. After inspection, the case is coated with a liner, similar in composition to the propellant, which is bonded on and cured to ensure that when the case is filled there will be no tendency of the propellant to break away. The propellant is mixed in batches of 300 US gal, which are transported in cans and pressure-fed into the case in succession. The motor is then cured for several days. The loaded assembly, weighing some 30,000lb, is finally sealed by the hemispherical end-closure, retained by a quick-thread screw, on which are hung the four swivelling nozzles. The latter undoubtedly posed the largest single propulsion problem, but Thiokol can now run first stages for their full burning time of more than a minute and guarantee satisfactory operation. The bold decision to employ such nozzles, instead of jetevators, results in reduced drag and slightly lower weight. Each nozzle pivots about the axis pointing to its diagonally opposite partner, and one pair can move differentially to provide roll control.

Contractor for the second stage is Aerojet-General, "with limited back-up by Thiokol, stressing different technological approaches." The propellant is of the polyurethane family

STRATEGIC MISSILES

	Propulsion		Length (ft)	Body diam. (in)	Launch weight (lb)	Range (n.m.)	Burnout Mach number	Estimated warhead (megatons)
	Thrust (lb)	Propellants						
SM-65 Atlas D	2×150,000+60,000	LO_2+RP-1	82.5[1]	120	255,000	9,000	26	3
SM-65A Atlas E	2×164,500+60,000	LO_2+RP-1	82.5	120	260,000	10,000	27	3
French IRBM	two stages	solid	50?	—	—	2,000	—	0.5?
SM-78 Jupiter	150,000	LO_2+RP-1	60.3	105	110,000	1,500	12	1.5
SM-80 Minuteman	three stages	PBAA/PU	59.5	71	65,000	5,500	22	2
Polaris A-1P	two stages	PU/AP	28	54	28,000	1,200	10	0.5
Polaris A-2P	two stages	PU/AP	28	54	—	1,500	12	0.5
Polaris A-3	—	—	31	54	—	2,500	15	—
SM-62 Snark	10,500	JP-4	69[2]	—	50,000[3]	5,500	0.93[4]	4
Soviet ICBM	more than one stage	—	—	—	300,000?	8,000	26	—
SM-75 Thor	150,000	LO_2+RP-1	65	96	105,000	1,500	12	1.5
SM-68 Titan 1	2×150,000+80,000[5]	LO_2+RP-1	98	120	220,000	8,000	26	4
SM-68B Titan 2	2×170,000+85,000[5]	N_2O_4+UDMH/H	108	120	270,000	12,000	28	5

Notes: 1, 75ft with Mk 2 re-entry vehicle; 2, without probe; 3, without boosts; 4, impact of warhead is supersonic; 5, in vacuo.

with which Aerojet achieved such great experience in the Polaris programme, and again an aluminium additive is resorted to. After a protracted competition, the contract for the third stage was resolved in July in favour of Hercules Powder Co, who claimed "higher potential performance" than their rivals. Thrust termination in this final stage is achieved by the explosive opening of circular ports in the forward-facing closure bulkhead, which in a few milliseconds changes the thrust on the re-entry vehicle from a positive to a negative value.

Minuteman is guided by an inertial system by NAA Autonetics Division, incorporating several new refinements. One of the most significant is that the airborne digital computer, which is itself much smaller even than that developed by Bosch Arma for Titan, not only processes the guidance data into steering commands but also helps to monitor the internal systems before launch. The airborne guidance is fully transistorized, and an unofficial estimate of its weight is 180lb. Internal electric power comes from auto-activated Ag-Zn batteries, and the a.p.u. employs a solid fuel.

As already noted, new techniques have led to a warhead and re-entry vehicle of a very advanced type. Warhead yield is probably of the order of 2MT, and doubtless it may be expected that improvements in guidance and circular-error probability will result in effectiveness comparable with that of the larger warheads of the first-generation ICBMs. Contractor for the ablative nosecone and re-entry vehicle is Avco Corp.

Present plans call for roughly 600 Minutemen to be deployed by the end of 1964. The bulk of these will be lowered into holes in the ground, dug in three general areas of the continental United States. Each silo will be utterly alone in an unmanned 2-acre plot, the only installation being a small underground checkout console linked to the missile by underground cables. After final assembly by Boeing at USAF Plant 77, at Hill AFB, the Minuteman will be loaded aboard a squat General Motors transporter/erector vehicle, consisting of a 275 h.p. prime mover and a three-axle trailer linked by a rectangular box in which the missile rides on air-suspension units. Arrived at the emplacement, the box is elevated vertically and the missile lowered gently into the silo. Finally the re-entry vehicle is brought up separately and mated with the missile's nose. After 5,200 model tests and seven full-scale firings with cut-grain "battleship" missiles at Edwards AFB, it was finally determined that it is possible to launch a Minuteman from a simple hole, even though the searing flame from the first-stage engine envelops the missile during departure.

First silo-based Minuteman squadron is scheduled to achieve initial operational capability in the summer of 1962, a year ahead of the original schedule. Armed with 55 missiles, it will be first of three squadrons of the 15th Air Force, based at Malmstrom AFB, near Great Falls, Montana. Ultimately there will be three Minuteman complexes like Malmstrom, each housing three squadrons of about 50 missiles. Each squadron will have five launch control posts, normally handling 10 missiles apiece but having the ability to launch all 50. Helicopters, probably Kaman H-43Bs, will take security guards on their tours of inspection round the silos. Total base costs per squadron are put at the remarkably low figure of $20m. The first contract for Malmstrom should be let in January, and the first squadron take possession 18 months later.

Able to range over about half of the 250,000-mile rail network of the United States, the mobile Minuteman is a new but entirely logical concept, being turned into hardware by AMF-ACF. A Minuteman train will consist of three to five launch cars, each housing a single Minuteman horizontally, together with a launch-control car, communications vehicle, one or two power cars to serve the numerous electric and conditioning systems, and a number of passenger coaches for the SAC launch crews. It has yet to be decided whether the Air Force will buy locomotives or hire them when they are needed from convenient railways (or even make the Minuteman trains parasites on already scheduled passenger or freight services).

There are at present expected to be five squadrons of mobile Minutemen, each consisting of ten trains. At the time of writing there seems no reason to doubt that all 50 trains could be continuously operational, except for their need for routine maintenance and for the fact that they must at times pass through cities or tunnels which would render them unable to fire. The essence of the idea is that it should never be possible to predict the future position of any train. Normally a train would station itself—for anything from a few hours to a matter of weeks—in a convenient siding, the co-ordinates of which could be fed into the guidance system with great precision. In emergency, however, and with slightly reduced accuracy, missiles could be fired with the train stationary on the open road.

Assembly of flight-test Minutemen is now in full swing, and it is worth stressing that from the outset flight trials will take place on vehicles little different from the operational missile. All three stages will be fired, and at an early date the guidance, control system and re-entry vehicle will be flown. The first shot from the Cape should take place in about six weeks' time, and as many as 80 missiles may be fired down the Atlantic Missile Range and by the 394th Strategic Missile Squadron—the operational training unit at Vandenberg AFB—by the time IOC is achieved in August 1962.

Polaris

Ballistic missile for launching from submerged submarines

US NAVY

THE successful firing of two Polaris missiles from the first Fleet Ballistic Missile Submarine on July 20 must be regarded as perhaps the most significant single accomplishment in the whole history of guided weapons since 1943. The occasion was the culmination of a single-minded development programme in which, faced almost until the end with official incredulity and lukewarm support, the *ad hoc* Special Projects Office and their team of industrial contractors succeeded in lopping three years off the original schedule. An extensive account of the complete Fleet Ballistic Missile System and of its test programme appeared in our issues of July 22 and 29.

After rejecting the concept of a seagoing Jupiter in 1955, the Navy rather half-heartedly began to study solid-propellant missiles as being better suited to shipboard conditions. By September 1956, by which time the Missile and Space Division of Lockheed Aircraft and Aerojet-General were firmly committed under study contracts, revolutionary technological advances in the fields of specific impulse, guidance and the re-entry vehicle, combined to bring down the launch weight for a 1,500 n.m. range from 160,000lb to around 30,000lb. Lockheed quickly sketched a two-stage vehicle only 28ft in length and the dream of submarine launching appeared attainable. While Lockheed worked feverishly to develop the missile and evolve a method of launching, the Navy demonstrated surprising confidence in the outcome by slicing through a nuclear submarine already on the stocks of the Electric Boat Co and inserting a completely new section aft of the "sail" to house vertical launch tubes for 16 Polaris.

After extensive investigation it was agreed that the missile could not be fired in the tube, since even a low-order explosion in the first stage could destroy the submarine. Instead high-pressure air is fed to the base of the tube and the missile discharged upwards like a torpedo. Its momentum carries it up to the surface at a speed high enough for natural hydrodynamic instability to cause little deviation from the vertical path, and the first-stage engine is fired as soon as the missile breaks the surface.

As a vehicle Polaris introduced many dramatic advances. Both the first and second stages consist of 54in-diameter cylinders of immense bursting strength formed from wrapped and welded thin steel sheet with a u.t.s. of around 300,000lb/sq in. These cases at one time were critically notch-sensitive, but are now a standard production job by several subcontractors. In them Aerojet-General cast polyurethane/perchlorate composite solid propellant, with an aluminium additive to prevent unstable combustion and increase specific impulse. Both stages have four nozzles with jetevators to provide trajectory control, and the second stage incorporates blowout ports around its forward-facing closure bulkhead to ensure precise thrust termination. A book could be written about the nozzles, ignition and destruct systems.

Contractor for the re-entry vehicle is Lockheed, who evolved a revolutionary configuration which has since become quite conventional. During the launch and subsequent hypersonic exit from the atmosphere the heat-sink nosecone is protected by a special shroud of rigid plastic material. The thermonuclear bomb inside was also a dramatic advance on previous designs. Although its yield of about 0.5MT is only modest for a strategic weapon, it has been strongly hinted that this is compensated for by exceptional guidance accuracy; the ideal CEP may well be of the order of half a mile. Shipboard inertial guidance is by NAA Autonetics and Sperry, celestial monitoring being accomplished while submerged by a Type II stabilized periscope. Very soon all-weather fixes on Transit satellite transmissions will be achieved with the Nortronics radiometric sextant. Airborne guidance is all-inertial, the MIT systems being produced by two industry teams led by GE and Hughes.

At present the US Navy have four FBM Submarines in commission (the first two have fired missiles), at least six more under construction, a total of 21 authorized and a stated requirement for 45. The first five ships have a displacement of 5,400 short tons surfaced and 6,700 submerged, and are 380ft long. The next (*Ethan Allen*) class are 30ft longer and have displacements of 6,900/8,600 tons. It is pos-

Launch of A-1X Polaris from submarine USS "George Washington" In the Atlantic on July 20 (the second of two fired that day)

sible that the obvious stretch is an extension to the missile bay enabling these ships to carry more than 16 Polaris each, but this has not been officially confirmed.

Flight trials with vehicles similar in shape to Polaris began at Cape Canaveral in September 1958. In August 1959 the first AX test missiles were launched from a surface vessel at sea and from a ship-motion simulator at the Cape. Last January Lockheed launched the first fully guided A1X; a cut-grain missile was launched from under water off the Californian coast on April 14, and the first FBM submarine, *George Washington*, shot two hot rounds from a depth of about 90ft (rather greater than the normal operational depth) on July 20. The second ship, *Patrick Henry*, fired four missiles successfully between October 15 and 18, and well before the end of the year both she and her predecessor are expected to vanish into the ocean depths to take up their operational stations.

The FBM mother ship, USS *Proteus*, is likely to be based at a port in Northern Scotland. At sea each submarine will have two complete crews, known as "Blue" and "Gold," and while on station the craft will be continuously at instant readiness. The point has been made that, since they should remain operational hours or days after the start of a total war, they would not need authority from heads of state to go into action but would soon obtain a clear picture of the situation from the world's commercial radio stations.

It is an open secret that there is strong American pressure, supported by Gen Norstad, SACEUR, for the deployment of a land-based Polaris derivative throughout the NATO nations. This would at once give NATO an offensive strategic capability possibly out of keeping with the defensive purpose for which the organization was founded. Both full-scale and smaller Polaris missiles have been investigated for land deployment. Detailed studies have been made for launchers based on road and rail vehicles, and it is possible that some arrangements retain the principle of pneumatic launching from a tube.

Snark

Strategic subsonic-cruise missile for fixed or mobile deployment

US AIR FORCE

A HISTORY of the development of this unusual pilotless bomber was contained in our 1957 review. Although highly vulnerable to interception, Snark is still the only intercontinental missile in the West which can approach its target along any desired trajectory; its reliability and accuracy are both good and its payload is greater than that of any ballistic missile in service.

Manufactured by Northrop's Norair Division as the SM-62A, Snark is powered by a Pratt & Whitney J57-P-17 turbojet mounted in the extreme rear of the slender body and fed with 26,000lb of fuel from internal and underwing tanks. The complete weapon system comprises little more than the missile and its wheeled launcher, both of which are air-transportable. The weapon is launched by a pair of 130,000lb-thrust boost motors, both fitted with jetevators to control the initial trajectory. The guidance system was the first ever to be developed for an intercontinental missile. From 1946 Northrop (now Nortronics) evolved the Mk 1 stellar-monitored inertial system capable of putting the warhead in exactly the right place after a flight of 11hr. The warhead separates from the rest of the missile to describe a ballistic trajectory to its target.

In April 1957 the decision was taken to put Snark into the Strategic Air Command inventory, and the following December the 556th Strategic Missile Squadron was activated at Patrick AFB. During 1958 the Squadron achieved many successful full-range and out-and-return missions (the missile being recovered in the latter cases). In July 1959 the squadron was redesignated the 702nd Strategic Missile Wing, based at Presque Isle AFB.

Soviet Missiles

AS in previous years, the Soviet Union has continued to protect all details of its strategic weapons. It is clear, however, that the somewhat rudimentary strategic weapons developed in the pre-1955 era have been superseded. At the beginning of the year the official Russian newsagency announced that multi-stage carrier rockets of a more advanced type would be fired over a new range—which could hardly be fully instrumented—terminating in a designated area in the Pacific. The first missile was fired on January 20. It travelled about 7,760 miles and impacted in the target area very near the designated spot. The miss-distance was given as 1.25 miles. A second rocket concluded this series of tests on January 31.

On June 28 a further announcement warned of tests between July 5 and 31, into a revised Pacific area about 1,000 miles south-west of Hawaii. On the evening of July 5 it was stated that a "new type of multi-stage carrier rocket for space exploration" had been launched on that day. The announcement went on, "The rocket was started strictly at a fixed moment. The flight proceeded in exact accordance with the preset programme. The dummy of the last stage, adapted for passage through dense layers of the atmosphere, reached the water surface in close proximity to the target, about 13,000km (8,078 miles) from the launching site. Specially instrumented ships . . . obtained valuable results. . . ." Two days later, a second firing was stated to have proceeded again according to plan, the nosecone impacting on target. Having learned all she needed, Russia was terminating this series of tests.

Very little is known about other Soviet strategic weapons. On October 20 Prime Minister Kruschev announced: "Our country also has submarines with atomic engines armed with rockets." On page 713 is a drawing of the Soviet Army's small selective-range weapon seen in parades during the past three years, referred to in the "Tactical Missiles" section.

Thor

Intermediate-range ballistic missile for deployment from fixed, soft emplacements

RAF BOMBER COMMAND

AS Weapon System 315A the original USAF IRBM was produced as a crash programme within an incredibly compressed time-scale, in a period when no strategic ballistic vehicle had ever been fired. Relevant dates are: November 1955, USAF receipt of IRBM approval; December 1955, development contract signed with Douglas Aircraft; October 1956, first SM-75 delivered to USAF; January 1957, first experimental launch; September 1957, first full-range firing; December 1957, first flight with guidance; February 1958, first flight with separable nosecone; September 1958, first delivery to RAF; December 1958, first operational training launch by USAF crew; April 1959, first operational training launch by RAF crew; December 1959, complete WS-315A pronounced operational with RAF Bomber Command; October 1960, 100th Thor launch.

Of the 100 launchings, 73 have been completely successful and 13 partially successful; and 37 of the shots were not as an IRBM but as a booster for a space payload—a role in which Thor has excelled. Full descriptions of the missile were contained in our 1958 review (pages 862-872) and on May 22, 1959. The airframe is fabricated from etched and milled aluminium alloy. Propulsion is provided by a Rocketdyne MB-2, flanked by twin verniers, guidance is effected by an AC Spark Plug intertial system, and the re-entry vehicle is protected by a GE Mk 2 copper heat-sink nosecone. A total of 60 Thors are operationally deployed in eastern England by Bomber Command; there are four complexes, each with five squadrons, each squadron having three missiles on launchers. Further details of this force were contained in our issue of March 11, 1960.

Titan

ICBM for deployment from fixed hardened installations

US AIR FORCE

BEARING in mind the fact that the first American ICBM, Weapon System 107A-1 (Atlas) represented an exceptional march into unknown technological regions, it is not surprising that in 1953 the Strategic Missiles Evaluation Committee recommended that a second ICBM should be authorized as a back-up programme. Accordingly WS-107A-2 was activated and the prime contract was placed with Martin in October 1955. Since that time the complete programme has been one of the world's greatest military/industry efforts. Martin and the USAF jointly created a vast new plant near Denver as a separate division of the company entrusted solely with the task of producing the Titan missile. The company's total awards against this programme at present amount to $510m for airframe design, fabrication and testing.

Although the 107A-2 weapon system rode on the back of the first ICBM to the greatest possible degree, the USAF were careful to steer it along different technological approaches wherever these might be expected to give better operational performance. For example, Titan was designed as a true two-stage vehicle, the second-stage engine being ignited above the atmosphere. Instead of "balloon" tankage fabricated from stainless sheet as thin as cardboard, the Martin missile was designed as two stages of monocoque tankage fabricated from etched and machined longitudinal planks of a

special aluminium alloy. Moreover, the weapon was designed from the outset for fully hardened silo emplacement.

Contractor for propulsion is Aerojet-General, whose LR87 first-stage engine has twin gimbal-mounted chambers each rated at 150,000lb at sea level. The second-stage engine is the LR91, with a single gimballed chamber with an expansion ratio matched to space conditions. At launch, the hold-down clamps release after 4sec correct operation of all missile systems. The missile then rises vertically until pulled over towards its target by the radio/inertial guidance system developed by Bell Telephone Laboratories and Remington Rand. This system uses a ground-based digital computer which transmits continuous steering signals based on radar tracking of the missile during its flight up to second-stage burnout. Originally it was to be teamed with an inertial system, but the latter was transferred to Atlas (*q.v.*). Eventually an entirely new all-inertial system by AC Spark Plug will be used, but this will not be introduced until several Titan squadrons have received their missiles.

Departure from the vertical occurs roughly 20sec from lift-off, and first-stage shutdown comes 80sec later, at which time the missile is travelling at some 5,300 m.p.h. The first stage, 57ft long and 10ft in diameter, is then separated by four explosive bolts and slides away to the rear along channel sections with recirculating ball systems. (Stage separation in the earlier test Titans intended to accomplish this feat was assisted by four solid motors disposed around the base of the second stage.) After a programmed period of coasting, the gas-generator for the second-stage turbopump is started, and its exhaust dumped overboard through propulsive nozzles disposed uniformly around the second stage. These nozzles not only ensure a clean stage separation (for the solid charges are not fitted to production missiles), but also function as verniers. Thrust of the LR91 is 80,000lb in vacuum conditions, and it accelerates the re-entry vehicle to approximately 18,000 m.p.h. After second-stage shutdown the four verniers continue to provide thrust to ensure that the final velocity is exactly correct.

When this condition is met, reverse thrust, believed to be imparted by redirecting the same gas-generator efflux, pulls back the second stage, which is 41ft in length and 8ft in diameter and burns up on re-entry. Contractor for the re-entry vehicle is the Advanced Development Division of Avco, who originally worked on a heat-sink model but in 1958 switched to the far more attractive Mk 4 ablative design. The original blunt pattern was stabilized during re-entry from 300,00ft downwards by a gas-jet system governed by rate-gyros sensing angular acceleration. At present Titan's thermonuclear warhead is the largest carried by any ballistic missile.

Five bases, all in the 15th Air Force, have been announced for SM-68 Titan I, and Strategic Air Command crews are being trained by the 395th Missile Squadron of the 1st Missile Division at Vandenberg AFB. The five operational bases are Beale, Ellsworth, Larson, Lowry and Mountain Home. Each will house one squadron of nine missiles, with the exception of Lowry which has two (848th and 849th SMS). A Titan 1 squadron has three triple complexes each of the type depicted in the article "Deploying the Deterrent" elsewhere in this issue.

The launcher system is the responsibility of AMF, who recently received an $81.6m contract for the 36 launchers for the final four of the bases listed. Titan complexes are self-contained units in which launch and maintenance crews, 200 strong, could live and operate long after the area above had been subjected to nuclear bombardment. The silos themselves are roughly 160ft deep (170ft at Lowry), protected against nuclear attack by steel and concrete doors weighing approximately 200 tons each. Also underground are propellant tanks, power and control centres, radio-guidance silos and living quarters.

Although the hundred short tons of propellant is forced into Titan 1 with incredible rapidity, the entire operation has to start after the receipt of an alert to fire. Moreover, the loaded missile has to be hoisted to the surface during the countdown. About 18 months ago the very bold decision was taken to produce Titan 2, choosing a propellant combination such that the tanks could be filled days or weeks before firing, so that the missile could be held at almost instant readiness. At the same time the silo was re-engineered to enable the missile actually to be fired up the underground shaft, without having to be elevated to ground level.

Titan 2 is designed to have performance even higher than that of its predecessor. This was achieved partly by chosing storable propellants with a specific impulse slightly higher than that of Titan 1, and partly by increasing the capacity of the missile tanks. An indication of the increase in fuel load can be gained from the fact that the first stage is 10ft longer than that of Titan 1 and the second stage now has the full 10ft diameter of the first. The propellants chosen are nitrogen tetroxide and a mixture of hydrazine and unsymmetrical dimethyl hydrazine. The Air Force is currently engaged in administering an industry competition for the propellant-transfer systems and supporting services.

Titan 2 has been allocated to Davis-Monthan AFB, of the 15th Air Force, and to McConnell and Little Rock AFBs, both of the 2nd Air Force. These Titan 2 bases will each house two squadrons with three triple complexes each. The total number of Titans at present scheduled for emplacement is thus 108. Base costs per squadron (nine missiles) are running at roughly $40m.

Flight testing of Titan 1 started on February 6, 1959. The second stage was ballasted with water and the test was required merely to confirm the structural compatibility of the vehicle. On May 4, 1959, successful separation of a dummy second stage was achieved, followed on February 2, 1960, by a complete two-stage flight. The latter was described as a medium-range flight, and it was also the first occasion in which the guidance system was fully operational. On February 24 last the first attempt to achieve separation of the Avco Mk 4 re-entry vehicle was successfully accomplished, the data capsule being recovered from the designated impact point some 4,900 miles down the Atlantic Missile Range.

Ten full-range flights have now been completed with all systems functioning. Testing is at present in hand on the pre-production Titan J series, and a number of Titan V missiles have been delivered to Vandenberg to prove silo compatibility and for subsequent launching by SAC crews. The first operational squadron, at Lowry, is to be combat-ready in seven months' time. It is also worth noting that Titan will be the booster for Dyna-Soar, the Air Force's manned controllable space vehicle.

Launch of a Titan from Cape Canaveral at 0932 on September 28 last

Tactical

Blue Water

Guided artillery missile for mobile deployment

BRITISH ARMY

DEVELOPMENT of this missile is the biggest single task at present confronting English Electric Aviation's guided weapons division. As members of British Aircraft Corp, the company are well placed to bring it to the operational stage to a tight schedule, and the fact that it has been planned from the outset to meet a requirement for such a missile stated by the Standing Group of NATO should act as no mean spur. Those responsible for it have for four years acted as foster-parent to the Corporal missiles of the Royal Artillery, and so have acquired valuable experience with the weapon which Blue Water is intended to replace.

No details of the weapon system may be divulged, apart from the missile's appearance and dimensions. It is reasonable to suppose that it will be fired at high elevation from a translauncher carried on a powered chassis, will have boost/sustainer solid propulsion, inertial guidance controlling the trajectory by the cruciform of moving wings, a variety of warheads up to nuclear devices of at least 10kT yield and a reaction time measured in seconds. During the past year there have been several high-level discussions with West Germany with a view to deployment of Blue Water by both nations; several reports have suggested that its development might also be shared. Further notes on the weapon appeared in our September 16 issue.

Caisseur

Cruise-type artillery missile

FRENCH ARMY

DEVELOPED by Sud-Aviation as the Type 4200, the Caisseur (Smasher) is a miniature aeroplane launched from a truck by solid boost motors and cruising on the power of an integral ramjet. Guidance is by radar and radio command, and the bomb is carried externally. Development took the weapon to the operational stage but has now ceased. Further details were contained in our 1959 review.

Corporal

Ballistic artillery weapon system for mobile deployment

US ARMY AND BRITISH ARMY

DESCRIBED in detail in our 1956 review, this slender missile was one of the first to be developed in America, and it achieved initial operational capability in the autumn of 1953. Guidance is effected by Gilfillan preset and radio command, propulsion is by an acid/aniline rocket with jet deflection and a large conventional or nuclear warhead can be carried.

Davy Crockett

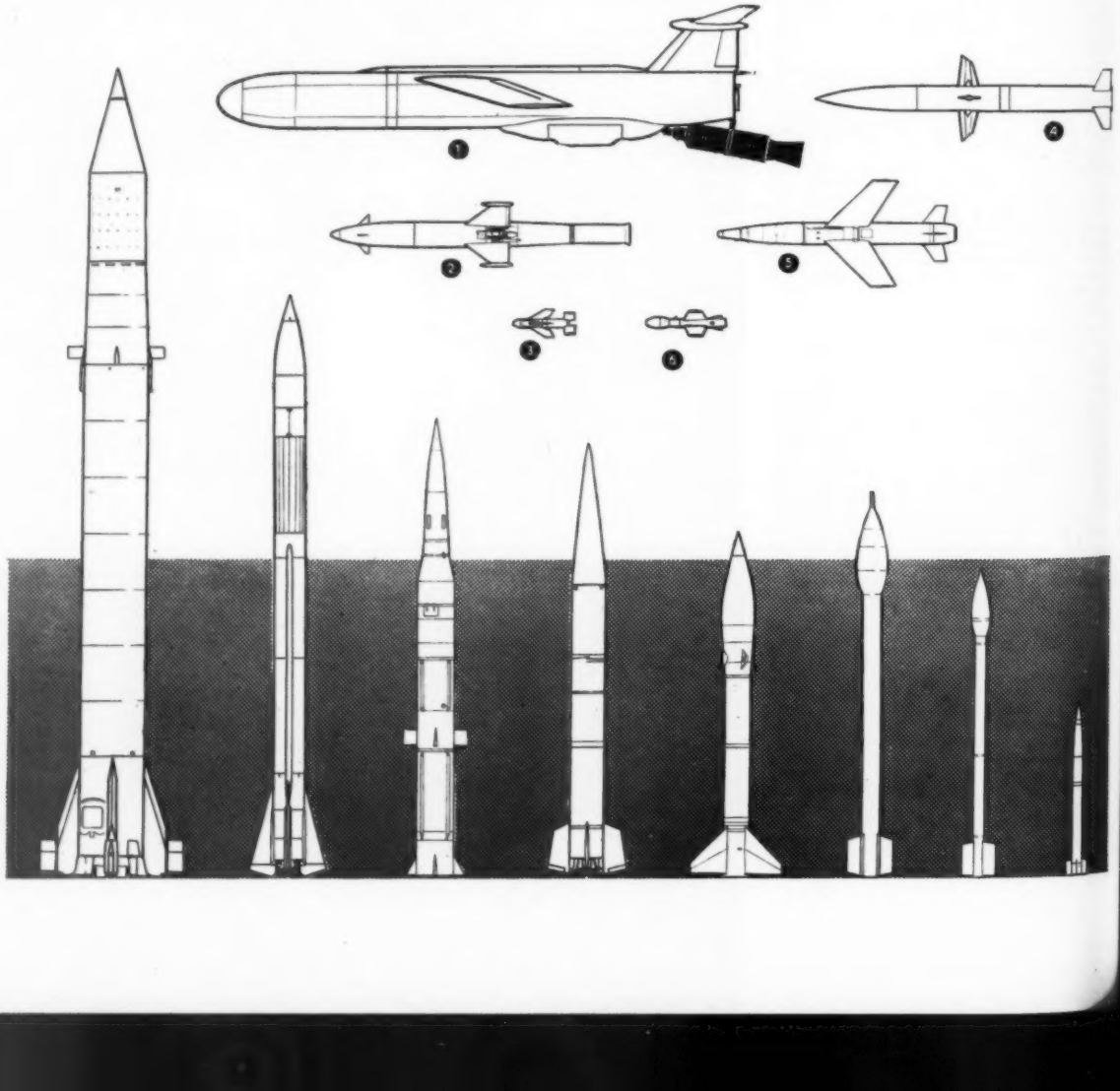
Unguided battlefield rocket

US ARMY

ALTHOUGH unguided, Davy Crockett is worthy of mention in this catalogue. The missile itself is a rocket-propelled spin-stabilized device, launched from a recoilless gun. One form of launch tube can be carried and operated by two men, while two heavier versions, tailored to different ranges, are for vehicular mounting. When the rocket motor is inserted into the launcher the warhead projects beyond the muzzle owing to its larger diameter. Either sub-nominal nuclear or conventional charges can be carried.

Funds from the current fiscal year have been requested for 6,247 Davy Crocketts (presumably this is the number of missiles, the number of launchers being less). Titanium Metals Corp of America comment that the project will require 2,000,000lb of titanium over the next five years. In August it was stated by the Defense Department that, when the test programme is

TACTICAL MISSILES: 1, Mace; 2, Robot 315; 3, Tigercat; 4, Blue Water; 5, Lacrosse; 6, Nord 5512; the missiles standing upright are, from the left, Redstone, Corporal, Pershing (with extended nosecone), Sergeant, Honest John, the two Soviet weapons tentatively designated T-5B and T-5C, and Little John Mk 4. The tinted background panel represents a height of 25ft



TACTICAL MISSILES

	Propulsion	Range (n.m.)	Launch wt. (lb)	Length (ft)	Span (in)	Body D (in)	Speed (m.p.h.)	Warhead
Blue Water	Solid rocket	—	—[1]	25	81	24	—	h.e. or N
Caisseur	Internal ramjet	55	2,200	11.5	118		605	551lb
Corporal	20,000lb RFNA+A rocket	74	11,000	46	84	30	2,300	h.e. or N (20kT?)
Honest John ...	Solid rocket	13	5,800	27.2	109	30	1,250	h.e. or N (20kT?)
Lacrosse	Solid rocket	17	2,300	19	108	20.5	800	h.e. or N (5kT?)
Little John	Solid rocket	5	760	14.5	23	12.5	1,000+	h.e.
TM-76B Mace ...	5,200lb turbojet	1,200	15,500	44.1	274	54	600	h.e., N or TN
Malaface	RFNA/Furaline rocket	22	3,500	20.7	—	—	600	1,000lb+
Matador	5,200lb turbojet	500	12,500	39.6	344	54	600	h.e. or N
Nord S.S.12 ...	Solid rocket	3.5	150	6.25	32	—	450	60lb?
Pershing	2-stage solid rocket	300+	10,000	35[1]	—	38	3,000+	N (20kT?)
Redstone	75,000lb LO_2+alc. rocket	215	61,000	63[2]	144	70	3,300	N (TN possible)
Robot 315	Resonant duct	10	3,000	24	84	—	600	1,000lb?
Sergeant	Solid rocket	74	8,500	36	71	31	2,300	h.e. or N (20kT?)
Tigercat	Solid rocket	—	—	59.9	25.6	7.5	—	h.e.

1, without extended nosecone; 2, later versions have length of 69ft.

complete, the weapon will be available to the United Kingdom, warheads remaining in American control. The missile is scheduled to become operational next year.

Honest John

Spin-stabilized artillery rocket

US ARMY, AND ARMIES OF WESTERN GERMANY, JAPAN, BRITAIN AND SEVERAL OTHER NATIONS

DETAILS of this heavy artillery rocket were contained in our 1957 review. Essentially it consists of a 23in-diameter motor attached to a variety of conventional or nuclear 30in warheads. It is aimed by steering the wheeled launcher to the correct bearing and elevating for the desired range. At least 20,000 rounds have been delivered.

Lacrosse

Guided artillery missile for mobile deployment

US ARMY AND CANADIAN ARMY

AN outline to the background of this battlefield bombardment weapon was contained in our 1957 review. Originally the programme was supported by the Marine Corps, but this service dropped out at an early stage and Cornell Aeronautical Laboratory and JHU/APL continued development for the Army. The basic missile is an aluminium-alloy tube, housing a Thiokol solid motor, to which are attached a guidance section and any of a variety of conventional or nuclear warheads, four fixed swept wings and four movable tail controls. The missile is fired from a 2½-ton truck and is guided by a radio-command system, which can function in all weather conditions as was outlined in the 1959 review.

Prime contractor is Martin's Orlando Division, and although there has never been any suggestion of a crash programme, production has continued steadily since August 1957. Battalions have been trained at Fort Sill, and at the time of writing at least eight have been activated. Several have been deployed overseas, and the first to reach operational status in Western Germany gave a demonstration at Aschaffenburg in August. Late in 1958 the Canadian Army announced their intention of purchasing Lacrosse, partly for deployment in Europe.

Little John

Spin-stabilized artillery missile

US ARMY

AFTER a progressive series of refinements starting in 1956, the final Little John 4 is almost combat-ready. It is a much more slender higher fineness ratio than the first test missiles, and the fins are rectangular and of greatly reduced area. Little John's development has been managed by the Army Rocket and Guided Missile Agency; airframes are made by Emerson Electric and boost/sustainer propulsion is by Hercules Powder Co. The missile is carried on a single-axle trailer on a launcher rail which is steered in azimuth and elevated manually to give the required range. The missile and launcher can be lifted in any combat transport aircraft or helicopter. Operational battalions, each with four launchers, are nearing service.

Little John is regarded as a corps or division general-support missile. For the future the US Army is striving to find the answer to the problem of providing an entirely new, optimized family of weapons having the lowest possible weight and maximum range and accuracy, with miniaturized nuclear heads. Most Army commanders are anxious not to have to introduce guidance systems, and much work is in hand finding the best way of launching a small weapon on a ballistic trajectory. Little John is, with Lacrosse and Honest John (in its present form) scheduled to be replaced by a new missile called Missile B (see Missile A, overleaf). This would probably weigh about 1,200lb, have a range of 3,000 to at least 50,000yd, have solid propellant of very high impulse and any of a variety of forms of spin stabilization.

Mace

Subsonic-cruise bombardment missile for mobile or hardened deployment

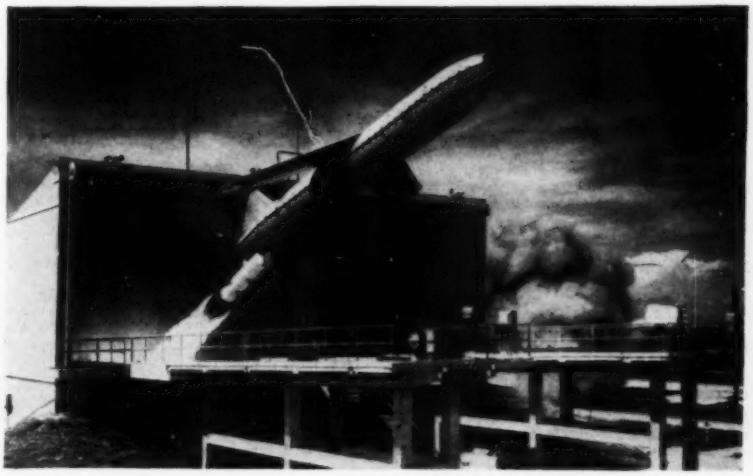
US AIR FORCE (OVERSEAS DEPLOYMENT), FRENCH AIR FORCE, WEST GERMAN AIR FORCE

DEVELOPED from the earlier Matador, Mace is a far more effective weapon; its payload/range performance is greater, its method of deployment is improved and it overcomes the line-of-sight limitation, and susceptibility to countermeasures, of the earlier missile's guidance system. Superficially it differs only in having a smaller wing and bigger body; it is similar in being fabricated largely from metal-honeycomb panels and shipped in packaged sections for assembly in the field.

After launch by a Thiokol booster of approximately 100,000lb thrust, cruise propulsion is provided by an Allison J33-A-41 turbojet rated at 5,200lb. All portions of the system are airportable and mounted either on the Translauncher (Goodyear) or Teracruzer (Four Wheel Drive Auto Co). After reaching a suitable location the complete system can be ready for firing in about an hour and held at a reaction time of a few minutes. Alternatively the weapon can be launched from fixed hardened bases.

The first version of Mace is the TM-76A, with a range of "over 650 statute miles" and guidance by the Goodyear Atran system which compares the terrain below with the programmed flight path plotted over a strip map. This version was deployed to West Germany last year with the 38th Tactical Missile Wing. The data below refer to the longer-range TM-76B, guided by an AChiever inertial system by AC Spark Plug. This variant is now in full production at Baltimore, at a cost (including Government-furnished engine, booster and guidance package) of no more than $250,000 per copy. USAF squadrons are to be deployed in Europe and Okinawa. At least 100 TM-76Bs have been purchased by the Federal German Government for the Luftwaffe, a further quantity, supplied under MDAP, will arm a squadron of the 1er Catac of the French Air Force, and the Japanese have expressed their desire to buy some.

Above is depicted a Lacrosse of the US Army about to explode on its target at White Sands; below is the launch, on September 21 last, of a US Air Force Mace from a prototype hard shelter



Approaching conventional artillery—of far less range or striking power—in ease of deployment, Sergeant can be unpacked and assembled for firing in a few minutes by a four-man launch crew

Malaface

Command-guidance cruise missile

FRENCH NAVY

IN most essentials this miniature-aeroplane missile is a variant of the ASW Malafon. Not having to lower its payload gently into the water it needs no parachute, and the space made available is occupied by a small sustainer engine which extends the range to about 25 miles. It is to be launched by the escort ship *La Galissonière* and later vessels against small ships or beaches under assault.

Matador

Subsonic-cruise bombardment missile

US AIR FORCE (OVERSEAS DEPLOYMENT)

APPROXIMATELY 1,200 TM-61 Matadors were delivered before production at the Martin Company's Baltimore division switched to the Mace in 1958. Matador squadrons are deployed in Western Germany and Formosa, and a training unit is stationed in Florida. A history and description of the weapon appeared in our 1957 review.

Missile A

Lightweight artillery missile

US ARMY

THE official statement by the Department of Defense runs "Evaluation of feasibility studies of Missile A have been completed, and the component-development phase of this rugged and highly mobile missile is under way. It will be used in direct support of the Infantry Battle Group. Missile A will be a member of an ultimate family of second- or third-generation missiles known at present as Missiles A, B, C and D. Missile A, the short-range member of the family, will be transportable by helicopter and usable in airborne operations. Missiles A and B are planned as replacements for Honest John, Little John and Lacrosse." Features would include a nuclear warhead, a launch weight of under 500lb and solid propulsion over a range of up to about 15 miles.

Pershing

Selective-range ballistic missile

US ARMY

ULTIMATELY the US Army hope to deploy four completely modern and optimized weapon systems which, in increasing order of range, will be known as missiles A, B, C and D. Only Missile D is in existence and this is the Pershing. Intended as a replacement for Redstone, its development could not be authorized until mid-1958, when a memorandum by a former Secretary of Defense, forbidding the Army to have a weapon with a range greater than 200 miles, was countermanded. Development of Pershing had for some time previously been in hand at the Army Ballistic Missile Agency, and the prime contract was placed with Martin's Orlando Division.

All portions of the weapon system have been made air-portable, fully mobile on the ground and far smaller and simpler than the corresponding parts of the Redstone system. The missile itself is powered by tandem solid motors by Thiokol, the first stage having a high-impulse composite propellant and a single nozzle with jet deflection. Ahead of these tandem propulsion sections is a bay containing the pure-inertial guidance system by the Eclipse-Pioneer division of Bendix, and on the front of the weapon is the pointed nose and nuclear warhead. Trajectory control is assisted by powered delta fins and by large rectangular surfaces at the rear of the second stage. The precise operational configuration of Pershing cannot yet be determined, since the most recent test missile carried an extended nosecone (as shown in the scale drawing on page 718).

A complete Pershing battery is transported on four XM474 tracked vehicles, by Food Machinery Corp. Each XM474 is about 202in long, 100in wide and 76in high, weighs 11,000lb and has excellent cross-country mobility. One carries the missile, minus warhead, on its transporter/erector/launcher (TEL); the second carries the warhead and azimuth-laying equipment, the third is filled with communications gear and the fourth houses the fire-control unit and power pack. When the firing site has been reached, the TEL lowers the launcher, hinged to outriggers at the rear, to form a simple ring levelled by three vertical legs and rotating in azimuth. The second XM474 backs up to the first for the attachment of the warhead, and the complete missile is then elevated vertically over the launcher. The TEL has four pneumatic tyres to enable it to be manœuvred independently of the XM474. After the short erector arm has been lowered, the missile stands alone except for the re-usable umbilical mast.

Total reaction time is extremely brief, and in a recent demonstration at Bad Kreuznach (W. Germany) the missile was brought across country at 40 m.p.h., negotiating a 3ft embankment on the way. On this occasion men of the 40th Artillery Group switched from Redstone to its replacement in a matter of days (they are, of course, not yet operational with Pershing). All portions of the system can be carried in C-123 Providers and the TEL, fire-control and power pack can be deployed by H-34 helicopter.

Martin Orlando's complex for flight-testing Pershing is the newest to have gone into action at the Cape. Designated Launch Area 30, it can check-out three Pershings simultaneously, and a point of particular note is that the ground-support equipment is not R and D but genuine tactical material; even the electronics in the blockhouse is identical with the operational equipment, although it is fitted into R and D consoles. The first flight was achieved on February 24; seven missiles have now flown successfully, the most recent being the first with a hot second stage (and an extended nosecone).

Redstone

Selective-range artillery missile

US ARMY

EXTENSIVELY described in our issue of May 23, 1958, this impressive missile was the direct American outgrowth of the German A4 (V-2), on which the largely German team gathered at Redstone Arsenal (later the Army Ballistic Missile Agency) began to work in 1950. Features include a Rocketdyne A-6 engine with refractory jet-deflectors, all-inertial guidance and a large separable warhead. All portions of the weapon system are mounted on wheels and most of it, including ground-support equipment, is manufactured by Chrysler. Operational capability was achieved in 1958 and one Field Artillery Missile Group (Heavy) is deployed in Western Germany. Redstone formed the basis of the booster which launched the first American satellite, and will also boost the first Mercury astronaut into space—but not into orbit—next year. As a weapon, it is to be replaced by Pershing.

Robot 315

Air-breathing bombardment missile for shipboard use

ROYAL SWEDISH NAVY

AN outline history of this weapon was contained on page 880 of our 1957 review. Launching is effected from an almost horizontal ramp under the thrust of internal solid motors, and cruise propulsion is provided by a resonant-duct engine. Lift is provided by a cruciform of wings, and the trajectory is controlled by a cruciform of forward control surfaces. Firing trials at sea began in April 1955, and two destroyers have been equipped with Robot 315 for approximately two years.

Sergeant

Tactical ballistic missile for mobile deployment

US ARMY

OWING to its early inception the Corporal (*q.v.*) is relatively complex, heavy, limited in performance and handicapped in mobility and reaction time. Sergeant shows what can be done today. The project began in 1954 to produce a versatile, fully mobile weapon system which would be effective in either a limited or a global war. Co-contractual responsibility was assigned to Jet Propulsion Laboratory and the Sperry Utah Engineering Laboratory, under the direction of the Army Rocket and Guided Missile Agency. Prime contractor for production is Sperry Utah, who co-ordinate the activities of more than 3,000 suppliers.

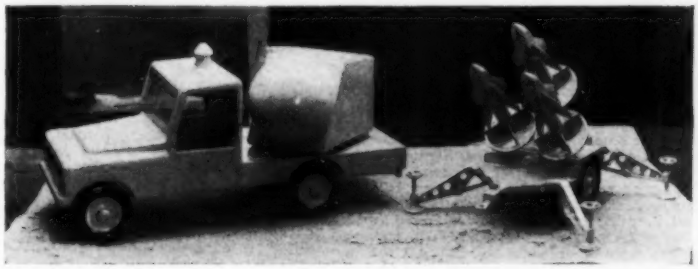
All portions of the system are mounted on standard prime movers, communications equipment being mounted on a four-wheel truck and the remainder being carried on articulated trailers with three-axle tugs. One transporter carries the Thiokol M53 motor, with 6,000lb of polysulphide composite propellant, cast in its steel case, the inertial guidance section and the four fins, each with a trailing-edge control surface linked to a refractory deflector in the propulsive jet; the fins are carried in individual flat packages and the motor and guidance in Temco light-alloy cylindrical containers. Another transporter carries two warhead packages, and the system is completed by the field-

maintenance test station, organizational maintenance test station and launching station. The latter carries the folding launcher, fabricated from new high-strength steels, an azimuth-orientation set, a gas-turbine generator and a firing set which serves as a data clearance centre.

Emplacement starts merely by pulling off the road to a suitable location and deploying the vehicles. The launcher tug is uncoupled, the generator set started, the outriggers positioned and the chassis levelled. Then the launcher superstructure is raised and the launching boom unfolded to provide a girder on which the sections of the missile are hung for assembly. First, the motor is brought up, its container opened and the complete unit hoisted up and attached to the launching hooks. Next, the guidance section is hoisted and rolled back for mating to the motor, after which the trolley from which it was suspended is removed. The weapon is completed by adding the warhead, with ram-home multi-pin electrical connectors, and attaching the four interchangeable fins. Target data are fed to the firing set, together with launcher position, warhead instructions and meteorological information, and the countdown is entirely automatic, the launcher adopting the correct azimuth and elevation shortly before firing.

As might be expected, the weapon system has been designed for air transportation and deployment in all types of terrain and environmental condition. It was announced on August 9 that every one of the 40 test missiles which had been fired at that time had been launched successfully. Missiles for inventory service are now coming off the line at Salt Lake City for deployment next year.

The Soviet army tactical ballistic missile said to be called T-1



Tigercat in model form: a triple launcher towed by a Land-Rover

Shillelagh

Lightweight bombardment weapon

US ARMY

LITTLE can be added to the official description by the Department of Defense, which runs "The Shillelagh is a lightweight missile system being developed for close-in support of troops. It will provide greatly increased firepower against armour, troops and field fortifications. In one application, the missile will be vehicle-mounted. The weapon is expected to become operational in the mid-1960s." Prime contractor is the Aeronutronics Systems Division of Ford Motor Co, and Raytheon are subcontractors for guidance. It is unofficially stated that the missile will carry a nuclear warhead and in one form be held in the hand.

Soviet missiles

THE Red Army was the first in the world to concentrate heavily upon artillery rockets, and truck-mounted batteries are progressively being improved. Larger, spin-stabilized rockets are mounted on at least three types of tracked chassis, and details of three versions, said to be designated T-5A, T-5B and T-5C, have been published in our 1958 and 1959 reviews. The middle-sized rocket, comparable to Honest John, has this year appeared with a parallel-sided warhead. Largest tactical weapon is a tail-standing device probably refined from the German "V-2" and able to transport a nuclear or large conventional warhead over a range of about 100 miles (see 1958 review).

Nord SS.12

Wire-guided missile for use in battlefield or air-to-surface operations

FRENCH ARMY

FORMING a logical extension of the Nord tactical missile family, SS.12 is much larger and heavier and carries a warhead weighing roughly four times as much. Moreover, although the wings are unswept, flight speed is even higher than the SS.11. Its maximum range is greater than that at which one can normally discern battlefield targets, and the high speed must extend the technique of wire-guidance to the uttermost (radio command is said to be under investigation as an alternative).

SS.12 cannot be used by infantry, but its zero-length launcher has appeared on a variety of vehicles including jeeps. The missile is large enough to carry several American nuclear warheads, but all official references speak only of conventional warheads for use against either hard- or soft-skinned targets. Since trials began late in 1958 the French Army have found the performance of SS.12 most encouraging, and production for inventory service is expected to start next May. Slightly modified versions are under development for the Aéronavale, the most important carriers being the Breguet Alizé and the Sud Frelon helicopter.

Tigercat

Guided missile for mobile deployment

PRIVATE VENTURE

WHEN Short Bros & Harland announced their development contract for the Seacat ship-to-air weapon, they stated that, as a private venture, work was in hand on a land-based derivative named Tigercat. Details are withheld, but it seems probable that a different type of guidance will be employed, since in this aspect of the programme Elliott Bros (London) Ltd are co-operating. Sketches and models reveal a large hemispherical dome in the centre of the launcher, much fatter than the guidance aerial dome for Seacat.

Carrying different types of warhead Tigercat could almost certainly be used in the anti-aircraft, anti-tank and general bombardment roles. One study involves a quadruple launcher mounted on a tracked, armoured chassis. A similar launcher can be put on the Unimog 4×4 truck, and a third alternative is for a Land-Rover to carry the guidance unit and tow a triple launcher mounted on a single-axle trailer provided with outriggers.

Nord SS.12 on its operational field launcher. This very effective weapon is being developed in forms matched to launching from ships, attack aircraft and helicopters

Air-to-Surface

Blue Steel

Strategic rocket-propelled cruise missile

ROYAL AIR FORCE

IT is clear from recent statements by the Minister of Defence that the introduction of Blue Steel Mk 1 to service is regarded as a matter of some urgency, in order to extend the penetrative ability of the V-bombers of Bomber Command. Prime contract for the development of Blue Steel was placed with the Weapons Research Division of A. V. Roe & Co at Woodford. During the past three years the company have managed the complete R & D programme, starting with two-fifths scale models to prove the basic aerodynamics and control, and going on to trial launches of full-scale test vehicles, initially unpowered, from Valiants and Vulcans. The powered test vehicles have been fitted with de Havilland Double Spectre rocket engines, and a number of these have now flown with full tanks at the WRE Woomera.

Although superficially similar to the test vehicles, Blue Steel Mk 1 has a more powerful engine, the Bristol Siddeley Stentor. This engine has large and small chambers, perhaps with sea-level ratings of about 16,000lb and 4,000lb, both fed by turbopump with HTP and kerosine from extensive tankage in the body of the missile (the location of which is suggested from a drawing on page 421 of our September 9 issue). The weapon is in production for the Vulcan B.2 and Victor B.2 aircraft of Bomber Command, each of which can carry one missile on the centreline. To achieve proper compatibility with the aircraft, the ventral fin can be folded to port until after take-off and the tips of the wings are tilted downwards.

Chief contractor for the guidance system is Elliott Bros (London) Ltd, who have produced a system which is partly or wholly inertial. During the outward flight the navigation systems of the bomber and missile continuously monitor each other until, at the moment of release, full position, velocity and acceleration information, together with altitude and target data, are fed into the missile guidance system. The weapon is then dropped and left to follow any desired profile to its final target, steered by foreplanes, ailerons and rudder. It cruises at high supersonic speed, and owing to Avro's experience with steel honeycombs may be able to maintain such velocity for extended periods at sea level. Blue Steel's radar cross-section is much less than that of a bomber, and it retains full ability to feint and manœuvre.

Originally there was to have been a Blue Steel Mk 2, but this completely redesigned vehicle—unofficially said to have ramjet propulsion—could not have entered service until 1965, by which time it would have been regarded as vulnerable. Instead, the obvious inbuilt stretch of Blue Steel Mk 1 is being realized in Blue Steel Mk 1★. Details of this weapon are restricted, but it may be expected to have greater range.

British ALBM

ON July 20 the British Minister of Defence, speaking in the Defence Debate, said, "Skybolt will cost a great deal less than Blue Streak because the R & D cost is being covered by America. Supposing that out of our spare resources we decided to diversify the deterrent and produce a missile as a partner to Skybolt which was entirely made by us, would the right hon Gentleman then change his policy again. . . ."

Bullpup

Radio-command weapon for use from any type of aircraft

US NAVY AND US AIR FORCE

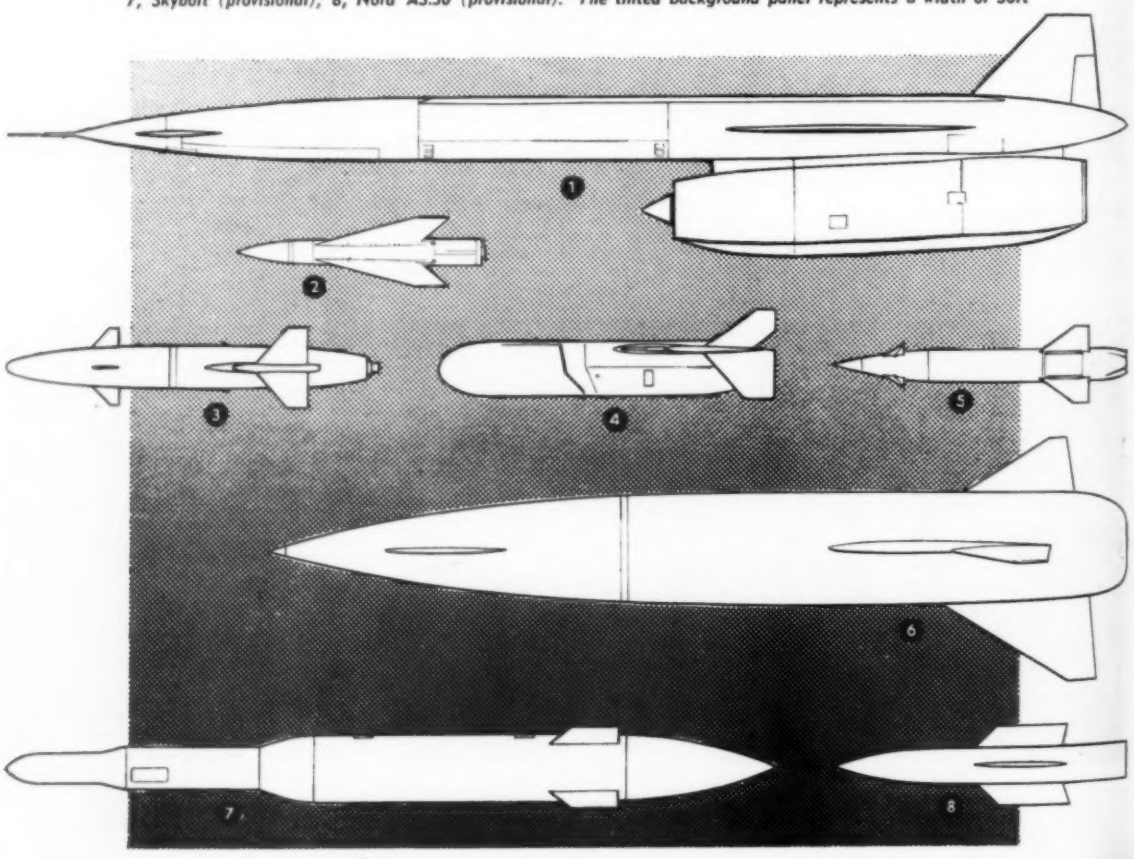
THE Navy's original ASM-N-7 Bullpup is basically a 250lb bomb fitted with a solid-motor, a rear wing cruciform carrying tracking flares and a nose cruciform of controls operated by radio-command from the pilot of the launch aircraft. This weapon became operational in April last year, and about 20 attack squadrons with the Atlantic and Pacific fleets are today fully trained in its use. Its effectiveness from such aircraft as the A4D-2 and FJ-4B so impressed the USAF that Tactical Air Command have adopted it as GAM-83A and deployed it with squadrons of F-100s and F-105s. Current production for both services has a more effective warhead, a pre-packaged liquid motor and an extended-range control system. In June of this year several rounds were fired from an HUS-1 helicopter under different conditions; one Bullpup, fired from 1,500ft, hit "within inches" of an orange target disc at the exceptional range of 10,000yd.

Martin's Orlando Division have for more than a year been under contract to the USAF for the development of the larger GAM-83B. This is regarded by the Air Force as the optimum command-guidance weapon for TAC for the immediate future, and it will be able to carry a range of conventional or nuclear warheads. All types of Bullpup can be simulated by the TGAM-83 training missile, produced by Martin's Baltimore Division.

Corvus

UNDER development for the US Navy by Temco, this long-range weapon for launching from carrier-based aircraft was cancelled on July 18. Development had cost $80m, and several successful flights had been made, guided trials having begun in March.

AIR-TO-SURFACE MISSILES: 1, Hound Dog; 2, Nord AS.20; 3, Robot 304; 4, Quail; 5, Bullpup; 6, Blue Steel Mk 1; 7, Skybolt (provisional); 8, Nord AS.30 (provisional). The tinted background panel represents a width of 36ft



An XGAM-77 Hound Dog test vehicle under a B-52 at Eglin AFB

Hound Dog

Strategic air-breathing cruise missile

US AIR FORCE

FOLLOWING research studies involving both the US Air Force and industry during 1956 and 1957, the USAF issued a specification in the latter year for a supersonic-cruise missile which could be carried by the Boeing B-52. Although several weapon systems, some purely concerned with countermeasures, were investigated in this connection, the prime requirement was for WS-131B, "to extend the effective lethal radius of the B-52 weapon system, improve its survivability and compound the enemy defensive problem." After an intense competition, the prime contract for the delivery vehicle, GAM-77 Hound Dog, was awarded to the Missile Division of North American Aviation Inc in August 1957.

NAA's team at Downey very quickly finalized the basic design as a canard propelled by an underslung turbojet and manœuvring by twist-and-steer with a rudder, ailerons and foreplane. The engine is a special variant of the Pratt & Whitney J52, with a rated thrust of about 8,000lb at sea level. It is installed in a nacelle optimized for supersonic flight and provided with a movable centre-body intake and a variable plug-type propelling nozzle in order to achieve optimum performance over a wide range of ambient conditions. Kerosine—likely to be JP-6, when this is released for service—is fed from tankage occupying the entire centre and rear fuselage sections. Forward of the tankage is the large thermonuclear warhead and the inertial guidance system by the NAA Autonetics Division, which is monitored celestially by star-trackers on the front of the launch pylons.

The latter are located under the inner wing sections of the parent aircraft, and the B-52H is believed to make provision for additional pylons between the engine nacelles. During the outward flight the navigation systems of the aircraft and Hound Dogs compare notes, but after the missile has been launched its control is inertial only. It would be logical to expect the missile to have the ability to manœuvre at supersonic speed at all altitudes. Flight testing started with limited-range flights down the Gulf range from B-52s operating out of Eglin. The first powered test vehicle flew on April 23, 1959, and the first production GAM-77 was launched on March 1 of this year. Flight testing has been extremely successful, and in the Senate Appropriations Testimony on March 23 Gen Bradley said, "In its operational configuration it has exceeded all performance goals." The following day Dr Herbert York described its development as "a factor of immense significance, extending the operational effectiveness of the manned bomber force." Deliveries to SAC squadrons have now begun.

Longbow

Tactical missile for destruction of enemy electronics

US AIR FORCE

SINCE 1956 the Radioplane Division of Northrop Corp have been actively engaged in R & D on a series of air-launched cruise missiles capable of homing automatically on to enemy radar installations and destroying them. The original vehicle was GAM-67 Crossbow, cruising at high subsonic speed (supersonic dash capability) for up to 200 miles on the power of a small turbojet. This missile has now been cancelled and replaced by Longbow, the vehicle portion of Weapon System 121B. All details are withheld.

Nord AS.20

Visual radio-command missile

FRENCH AIR FORCE, FRENCH NAVY AND LUFTWAFFE (WEST GERMANY); likely to be deployed in most NATO countries

OWING to its direct visual-alignment command type of guidance, the AA.20 (Nord 5103) missile system is inherently flexible and can be employed against any target which can be seen by the man who works the joystick control. In fact, aircraft armed with it could be employed directly in an air-to-surface role, with no modification whatever. Early flight trials at Cazaux confirmed this hope, and Nord accordingly produced the Nord 5110 missile specially suited to the changed function.

Since a proximity fuze is not required against ground targets the space previously occupied by this component made way for any of several much larger warheads, which each weigh 73lb and are detonated by a contact fuze either with or without a time delay. Many thousands of AS.20s are on order from Nord's major production facility at Bourges; the weapon has been adopted by the French Armée de l'Air and Aéronavale, and large orders are for missiles to be carried by Fiat G.91s of the Luftwaffe. The Italian Air Force intend to adopt the weapon, and several other nations have expressed their interest in it.

Nord AS.25

Radar-command missile

FRENCH AIR FORCE

IT has been reported unofficially that Nord have developed an air-to-surface variant of the AA.25 (*q.v.*) forming a radar-guided counterpart to the AS.20.

Nord AS.30

Radar-guided heavy tactical missile

FRENCH AIR FORCE

ALTHOUGH Nord have been precluded on security grounds from announcing the AS.30, this is known to be the designation of a new air-to-surface weapon appreciably larger than its predecessors. The first published reference to it appeared in the Italian journal *Alata*, which illustrated a weapon scaled directly from the AS.20 and included brief dimensions, weight and performance. Similar material was later published by Northrop, in associating the AS.30 with the Rapiere system, and showing it carried by the N-156F on the centreline and wing pylons.

Dassault may have slipped the French security traces in including a model of the AS.30 among stores which can be carried by the forthcoming Mirage IIIE. In this case the weapon was depicted as having wings of trapezoidal shape with a swept leading edge and axial tips. Guidance is of a radar or radio-command pattern, and the weapon can be operated from aircraft flying at supersonic speed. The missile is large enough to carry a 450 to 515lb nuclear warhead, has a proximity fuze and appears to fill a gap in the NATO (and British) armoury.

Quail

Decoy launched by manned bombers for their protection

US AIR FORCE

A UNIQUE weapon in the West's inventory, GAM-72 Quail has been developed by McDonnell Aircraft to provide a decoy vehicle which can be taken into a target area on board bombers of Strategic Air Command. It comprises the smallest possible airframe capable of carrying the required electronic and other countermeasures and having speed, altitude, and radar reflectivity comparable with that of a B-52.

Doubtless Quail is intended to be carried by all SAC bombers, but at present it is hung only on special racks in the weapons bay of B-52Gs. As the aircraft approaches its target the Quail (several combinations of Quails and weapons are possible) is switched to internal power with its General Electric J85 turbojet running. The decoy is then released, its aerodynamic surfaces unfold and it flies a course controlled by a pre-programmed guidance system. It forms a decoy flight pattern with the B-52 to confuse and dilute enemy warning networks and intercepter forces. Quails have been launched from B-52s and B-47s, and on June 24 a B-52G launched three down the Eglin Gulf Range in a single mission. It has been unofficially suggested that the decoy might be bought for RAF Bomber Command.

Robot 304

Transonic tactical missile

ROYAL SWEDISH AIR FORCE

PROJECT work on Robot 304 started in March 1950, and the first (unguided) test vehicle was launched on February 11, 1955. Developed specifically to increase the striking power of the Saab A32A Lansen, the missile entered operational service early last year and is now standard equipment with Attack Wings F6, 7, 14 and 17. The weapon has a rear wing with fixed fins at the tips, and is steered by a cruciform of forward control surfaces. Propulsion is effected by a two-stage solid propellant motor, and tracking flares assist the controller in the parent aircraft to impart radio command signals. Robot 304 is large enough to carry nuclear warheads, but Sweden has none.

Skybolt

Ballistic missile for launching from strategic aircraft

US AIR FORCE AND ROYAL AIR FORCE

IN their search for ever better mobility, dispersal, prospect of surviving an enemy nuclear onslaught and ability to penetrate hostile environments with their own thermonuclear delivery systems, the military scientists of the United States have for five years considered the possibility of launching a strategic ballistic missile from a manned bomber. The latter could fly most of the way to the target; during a "cold war" it could conduct standing patrols just outside the frontier of a possible enemy country, while for an actual delivery it could cross the frontier and fly towards its target.

By 1957 the Department of Defense and US Air Force could clearly appreciate the advantages of such a system. The warhead for despatch could not be destroyed by an enemy before launch, since to find it one would have to search literally millions of cubic miles of air. Its penetrative ability over the most difficult, final part of its delivery would be exceptional, for it would be inside a re-entry vehicle of small radar cross-section, travelling at hypersonic speed along a trajectory starting at an unknown point. For once, total weapon-system costs would be minimized, since the all-important launch platforms were already in existence in the squadrons of Strategic Air Command, and the launch crews would sit in the same seats in the same aircraft.

There were also other advantages. The steady progress of ballistic-missile technology was pointing the way to vehicles which, for a given megaton-mile payload/range were only a fraction the size of the first-generation weapons. It seemed possible that starting with a launching point 45,000 or more feet above the ground moving towards the target at over

AIR-TO-SURFACE MISSILES

	Propulsion		Length (ft.)	Span (ft)	Body D (in)	Launch wt (lb)	Range (n.m.)	Mach number	Warhead
	Type	Propellant							
Blue Steel 1	Stentor rocket	HTP+K	35	13	50	15,000?	300?	2?	TN (4MT?)
Blue Steel 1★	Rocket	—	—	—	—	—	300+	2+	TN
ASM-N-7 Bullpup	Rocket	Storable liquid	11.2	3.1	12	571	3	1.8	250lb
GAM-83B Bullpup	Rocket	—	—	—	12	750+	5+	2+	N (10kT)
GAM-77 Hound Dog	J52 turbojet	K	42.5	12.1	28	9,600	435+	1.6	TN (4MT)
Nord AS.20	2-stage rocket	Cordite-type	8.5	2.6	9.84	317	3	1.7	73lb
Nord AS.30	2-stage rocket	Solid	12.4	3.3	—	1,125	6	2	N
GAM-72 Quail	J85 turbojet	JP-4	12.8	5.4	2.1	1,100	200	0.9	n.a.
Robot 304	2-stage rocket	Solid	14.75	6.7	19.4	1,200	3+	1	550lb
GAM-87A Skybolt	2-stage rocket	PU/AP or PBAA	—	n.a.	—	—	1,000	9	TN (2MT)

500 m.p.h., it would be possible to design an ALBM (air-launched ballistic missile) capable of carrying a thermonuclear warhead 1,000 n.m., yet small enough to be carried on pylons under the wings of a Boeing B-52. Further study suggested that this great aeroplane could, in fact, carry four of the projected ALBMs. Priorities rose; and, such was the strength of the US missile industry in 1957, there was no need for a crash programme as there had been with the land-based IRBM and ICBMs.

Instead, the Air Force awarded study contracts to 14 major missile firms from October 1957, to make absolutely sure that the concept was technically feasible, and to determine what design goals should be set, what carrier aircraft should be stipulated and how the concept should be translated into hardware. The Air Force issued further funds during 1958 to enable several contractors to launch ALBM test vehicles from aircraft travelling at both subsonic and supersonic speeds. The studies supported the design concept, and in January 1959 the Air Force asked the contractors for specific design proposals. The entry by Douglas Aircraft was submitted to the ARDC in March, and on May 26 the company received a further contract to continue study of Weapon System 138A.

This time the study was to involve subcontractors. In August 1959 Douglas brought in Aerojet-General to produce the propulsion system, in September General Electric were asked to design the re-entry vehicle, and in October the Nortronics division of Northrop received the contract for the guidance system. On February 5 of this year Douglas received the prime research and development contract authorizing flyable hardware.

Designation of the missile portion of WS-138A is GAM-87A. The USAF Chief of Staff, Gen White, nicknamed the weapon Sky Bolt, but last summer this became officially accepted as a single word—Skybolt. From the outset, WS-138A was designed for compatibility with the Boeing B-52H and B-52G, with aircraft modification held to a minimum. Earlier versions of the B-52 may later be converted to carry it, but it is most unlikely that it will ever be mated with the B-47 or B-58. Moreover, since it is designed for transport outside the launch aircraft, it cannot be carried in its present form by the B-70; in any case, the time-scale of this 2,000 m.p.h. bomber is so different that this is of little consequence.

One of the fundamental requirements in planning WS-138A was that it would impose no degradation upon its carrier aircraft, apart from the inevitable ones of increased weight and drag (which the powerful B-52H can take in its stride). It was stipulated that take off should never be delayed, or the reaction time increased, owing to the necessity to perform ground operations on the WS-138A airborne equipment, apart from the need to maintain it serviceable. Accordingly the B-52H can be well on the way to its target, or on alert status on standing patrol, before the missile need be brought to life.

Almost the only new problem in the whole Skybolt system is that final delivery is accomplished by a ballistic vehicle launched from a point whose position and velocity can vary widely in all three dimensions (Polaris launch co-ordinates start precisely at sea level). Accordingly the bomber crew have to fly to the desired launch area and steer towards the target (to give maximum missile range) at the best height and airspeed, while the airborne systems measure every parameter very precisely. At the moment of launch all relevant data, including co-ordinates in three dimensions, ground-speed, airspeed, inclination of launch aircraft, accelerations about all axes, target position, and probably a few other things like the temperature of the missile propellant, are shot into the Skybolt guidance system and digested. Then the missile is on its own.

There are many ways in which an ALBM could be launched. For maximum range the carrier aircraft should probably pull up into a steep climb and release the missile on its desired ballistic trajectory, but there are some obvious drawbacks to this dramatic technique. Skybolt is just dropped from straight and level flight. After a time delay long enough to ensure a vertical separation of at least 100ft, the high-impulse solid propellant of the first-stage engine is fired. Until this time it would be logical to streamline the base of the missile by a jettisonable fairing, similar to that shown in the sketch, in order to achieve the maximum miles per gallon, and hence endurance on alert patrol, by the carrier aircraft.

One can assume that the first-stage engine will have not less than two nozzles, and that these will swivel to provide thrust vector control. As the Skybolt accelerates ahead of the bomber a pre-computed pickup programme arrests its fall and gradually places it on the correct climbing trajectory. The first stage then burns out, the second stage is ignited and the inertial guidance system assumes control by swivelling the second-stage nozzles. Nortronics say the guidance "is a natural development of the Mk 1 stellar-monitored inertial system and its test equipment for SM-62 Snark, LINS (lightweight inertial navigation system), A-5 astroinertial system and A-8 star-tracker for space navigation." This emphasis upon astro systems doubtless reflects the need to know the launch position exactly, even after many hours on patrol over unhelpful territory. But once the Skybolt has been released the guidance system has a relatively simple task, for it has to function for only about two minutes, so that gyro drift can be ignored. After reaching the exact velocity on the correct trajectory, the second-stage engine is ported forwards for precise cutoff, and the re-entry vehicle released. One may expect the latter to resemble the Mk 3 on a reduced scale. Nothing can now stop the warhead, which may have a yield of about 2 MT, from impacting on its target.

There are very few areas in WS-138A in which one might expect to run into trouble. The need to determine launch position and velocity in three dimensions causes nobody's hair to stand on end, and it is a straightforward task to design a lightweight rocket case capable of withstanding motor internal pressures and temperatures after being slung from points on its side under a manœuvring bomber in the freezing stratosphere. Throughout, the whole programme has been matched to existing states-of-the-art, and virtually every problem which it poses has been solved in an earlier programme. It is, therefore, not easy to understand on what basis British critics of the weapon have argued, following the announcement of the Minister of Defence last April that the United Kingdom was negotiating for the purchase of the missile for RAF Bomber Command (in lieu of Blue Streak).

Several political questions regarding British use of the American weapon remain to be answered. It is not yet clear whether or not British firms will manufacture any part of the missile or its associated equipment, and, in particular, where the warheads will come from. Britain has the ability to develop a thermonuclear warhead for Skybolt; and, from tests with two-stage Black Knights, it should be possible to produce a re-entry vehicle. The use of American warheads presupposes bilateral control at head-of-state level in order to satisfy US Atomic Energy Commission laws. Apart from these matters the deployment of Skybolt in Bomber Command is a natural. Two or possibly four missiles could be fitted under the wings of the Vulcan B.2s, and a more powerful (Olympus 21) Vulcan might well be matched to the weapon from the outset. Representatives of A. V. Roe are at present in Santa Monica, helping Douglas stow away the missile-system equipment in the Vulcan, and British firms will certainly have a major share in the aircraft modification programme. Douglas recently issued a block diagram (*Flight*, September 30) from which it is clear that, apart from the addition of underwing pylons, the chief Vulcan modification will be the installation of a pre-launch computer.

It is worthy of special note that a Vulcan carrying two Skybolts could attack two targets in one mission; and a B-52H, armed with two Skybolts, two Hound Dogs and its internal bombs, could wage a whole war on its own. This has reduced the number of aircraft needed to deliver a given thermonuclear yield against a given number of targets.

At present the development programme is about half way between contract authorization and first flight. System configuration was completed many months ago. Missile mock-up and aircraft/missile integration mock-up (for B-52 and Vulcan) have both been completed. Engine testing is in full swing at Aerojet, and successful static firings have been in hand for many weeks. Sled tests of the guidance system and drop tests with dummy missiles are close at hand, captive missile tests are probably three months away, programmed flight tests should begin late next summer and guided flight tests before the end of next year. The Atlantic Missile Range will be used, Eglin Gulf being too small.

All portions of the system are at present on schedule. Appropriation during Fiscal 1961 was $60m, a substantial figure for an R & D programme, and total system costs up to the end of 1965 are $800m, divided into $200m for R & D and $600m for inventory procurement. Initial operational capability with SAC is scheduled for 1964; and if Thor—a far more challenging programme, by the same prime contractor—is any guide, this schedule may prove pessimistic.

Wagtail

Low-altitude delivery system

US AIR FORCE

UNDER development by Minneapolis-Honeywell for at least four years, this weapon system poses exceptional problems and is still being closely protected by security. It is intended to be launched from a supersonic aircraft flying very close to the ground. After launch, retro-rockets reduce its speed, and the inertial guidance then steers it across country to its target at the lowest possible altitude. The guidance system has to sense obstructions well ahead, and steer the missile over or around them in sufficient time for the manœuvres not to be too violent for the aerodynamic surfaces. Propulsion by a solid rocket.

Surface-to-Air

Bloodhound

Semi-active radar homing system for area defence

ROYAL AIR FORCE, ROYAL AUSTRALIAN AIR FORCE AND ROYAL SWEDISH AIR FORCE

IN several respects this SAGW (surface-to-air guided weapon) system can claim to be a "first" or a "mostest". Outside the United States and Soviet Union its development has been the world's largest single missile programme. It is possibly the most important piece of hardware in the whole United Kingdom defence inventory, it was the first non-American anti-aircraft guided weapon to enter service and it was the first British missile to win an export order. Under the code name Red Duster the system has been developed during the past ten years by joint prime contractors, Bristol Aircraft and Ferranti Ltd, at a total cost (including directly associated radars) of £45m. Unlike several other British guided weapons, Bloodhound has never been criticized in the *Civil Appropriation Accounts*.

Production of the missile itself is the responsibility of a plant in Cardiff, S Wales, managed by Bristol for this purpose. On receipt by an Air Defence Missile Squadron of RAF Fighter Command the weapons are serviced on ground-handling gear by ML Aviation, who also make the zero-length launcher. The latter are arranged in Fire Units of 16, which slew in azimuth to follow the movement of the associated AEI Sting-Ray target-tracking and illuminating radar. Coded transmission from the latter is keyed to individual missiles, and the reflection from the target is received by the scanner dish in the nose of the missile while it is still on the launcher.

When the target is within range the Bloodhound is fired automatically at an elevation of 45°. The four solid boost motors accelerate it to high supersonic speed in about four seconds, and then drop off astern as a single unit. Ram air spins up the turbopumps which pass kerosine from the fuselage tanks to the twin Bristol Siddeley Thor ramjets mounted above and below the body. Finally, the moving wings are unlocked to govern the flight of the missile by twist-and-steer, according to the displacement of the receiver dish from the missile axis. The weapon flies a proportional-navigation course, and the large conventional (doubtless rod-type) warhead is exploded by a proximity fuze.

A history of the development of Bloodhound, a description of the Mk 1 weapon system and a cutaway drawing of the missile, were contained in our issue of October 23, 1959. Bloodhound Mk 1 has for some 18 months been deployed as an integral part of the defensive system of the United Kingdom against manned aircraft. Fighter Command bases equipped with it are completely tied in with the existing control and reporting network, and the Sting-Rays of the Fire Units are put on to their targets by Metrovick three-dimensional radars of high power. A visit to the first SAGW base was described in our November 7, 1959, issue. Late in 1958 the Royal Swedish Air Board purchased an evaluation quantity of Bloodhound Mk 1 weapon systems. These are now in Sweden, and they may be followed by an inventory order. Last year it was announced that Bloodhound Mk 1 had also been ordered for the Royal Australian Air Force.

At the recent SBAC Show preliminary details were given of Bloodhound Mk 2. In our issue dated September 16 we discoursed at length upon the shortcomings of pulse type radars, and of the manner in which continuous-wave equipment can be made with far higher resistance to countermeasures and with better target discrimination at very low angles of elevation. Bloodhound Mk 2 employs CW radar in order to achieve greater lethality against all types of target down to sea level, even in the face of highly sophisticated jamming techniques. The guidance electronics package carried in the forebody of the missile is radically different from that of the Mk 1 weapon, the circuits being fully transistorized, having wrapped wire joints, and being disposed on printed boards arranged transversely, instead of axially. It has also been stated that many other portions of the Bloodhound Mk 2 weapon system have been altered to confer much enhanced performance.

Launch of Bomarc A from operational shelter

Bomarc

Area-defence missile for operation from fixed bases

US AIR FORCE AND ROYAL CANADIAN AIR FORCE

SINCE 1949 this missile system has been under development as the surface-to-air missile of the US Air Force. Unlike the contemporary Nike system, Bomarc is intended for the defence of a wide area, and the missile itself is virtually a pilotless intercepter, originally designated XF-99, but restyled IM-99. Launched vertically by an internal booster rocket, the big missile accelerates until the twin Marquardt RJ43 ramjets light up to provide cruise propulsion. Mid-course guidance is effected by radio command from the SAGE electronic network of the continental US, and terminal homing is achieved by a fully active radar system by the Westinghouse Air Arm Division. Both conventional and nuclear warheads can be fitted, the latter being standard in NORAD (North American Air Defense System).

Prime contractor is the Boeing Airplane Co. From their Seattle plant came a large number of research and development missiles before the first pre-production IM-99A rolled out on December 30, 1957. Following prototype testing with these missiles, operational evaluation

(tactical) testing started in February of this year, using production rounds fired down the Gulf range from near Eglin AFB. The results were as follows: February 11, Flight-control malfunction in cruise; February 26, head-on interception of QF-80 at 31,000ft at 100 n.m.; May 12, direct hit, head-on, supersonic KD2U, 43,000ft, 150 n.m.; May 12, head-on interception, QF-80, 31,000ft, 125 n.m.; May 12, ramjet malfunction during boost phase; May 18, head-on interception, KD2U, by two missiles after flights of 100 and 150 n.m. at 43,000 and 46,000ft; May 18, head-on direct hit, QF-80, 33,000ft, 110 n.m.; May 27, head-on interception, QF-80, 30,000ft, 120 n.m.; May 27, head-on interception, KD2U, 20,000ft, 65 n.m.; June 2, redirection from QF-80 to quartering interception of KD2U, 46,000ft; 120 n.m.; June 2, control malfunction at end of cruise; June 9, interception of desired QF-80 from close formation, 25,000ft, 120 n.m.; June 9, head-on hit, QF-80, 21,000ft, 40 n.m.; June 16, astern interception, QF-80, 35,000ft, 30 n.m.; June 24, interception of diving QF-80, 9,000ft, 100 n.m.; June 24, malfunction in co-ordinate converter; July 28, malfunction in co-ordinate converter starter; August 5, head-on interception, QB-47, 40,000ft, 140 n.m.; August 11, crossing interception, QB-47, 35,000ft, 150 n.m.; August 11, head-on interception, QB-47, 35,000ft, 150 n.m.; August 18, head-on direct hit, QB-47, 15,000ft, 140 n.m.; August 19, internal malfunction.

Bomarc bases at McGuire, Suffolk County, Otis, Dow, and Langley AFBs are steadily becoming operational. Each houses one or two squadrons of 28 missiles, which are stored horizontally on their launchers in individual shelters which split open sideways. Reaction time is of the order of 90sec.

During the past three years Boeing's development effort has been directed at the IM-99B, which is superficially similar but has considerably better performance. The Aerojet liquid booster has been replaced by a solid rocket with jetevators by Thiokol. Cruise propulsion is provided by the improved RJ43-MA-7 engine, and the terminal-homing guidance is of a CW variety. Bomarc B was adopted by the RCAF in January 1959, following cancellation of the Arrow intercepter. Based at North Bay, Ontario, and Mont Laurier, Quebec, the Canadian Bomarcs will be tied in with NORAD, and Boeing have subcontracted manufacture of wings and ailerons to Canadair. In June funds were voted to assist the RCAF to acquire the missiles involved.

The first phase of Bomarc B testing took place down the Atlantic missile range between May 1959 and May 1960. Seven flights took place, most of which were failures owing to malfunctions in the cruise propulsion. Block 2 testing, from Eglin, has been more successful: April 13, successful flight without drone, 65,000ft, 150 n.m.; May 17, no drone, 65,000ft, 220 n.m.; July 8, interception of KD2U, 70,000ft, 200 n.m.; August 11, head-on interception of KD2U, 35,000ft, 170 n.m.; August 23, partially successful head-on interception of KD2U, 35,000ft, 170 n.m. Bomarc B is to be deployed at Duluth, Niagara Falls and Kincheloe AFB, the first base achieving operational capability next year.

Contraves/Oerlikon

IN our 1958 and 1959 reviews details were given of the anti-aircraft weapon systems evolved privately by Contraves AG and the Oerlikon Machine Tool Works, Bührle & Co, and since produced in quantity in Switzerland and Italy. Training firings with RSC and RSD missiles are being carried out in Sardinia, while an entirely new weapon system is under development. The only details which the group are prepared to divulge are that the new surface-to-air missile has "a solid-propellant rocket motor and a new guidance system."

French missiles

PREVIOUS missile reviews have published details of the extensive work carried out by all three French services on missiles in the surface-to-air category. Actual weapon systems investigated included the Matra R.422, the Nord ACAM, the DEFA Parca, the Sud 4300 and 4400 Trident, and the Navy's Maruca, Masurca and Masalca. In the event, France has wisely decided to accept American weapons for land-based air defence, in the form of the Nike family, available under MDAP, and the Hawk produced by a co-operative programme by five NATO nations. Parca remains in service as an Army training weapon, and Masurca is now the only French anti-aircraft missile in active development.

Hawk

Mobile weapon system for defence against manned aircraft at all altitudes up to 60,000ft.

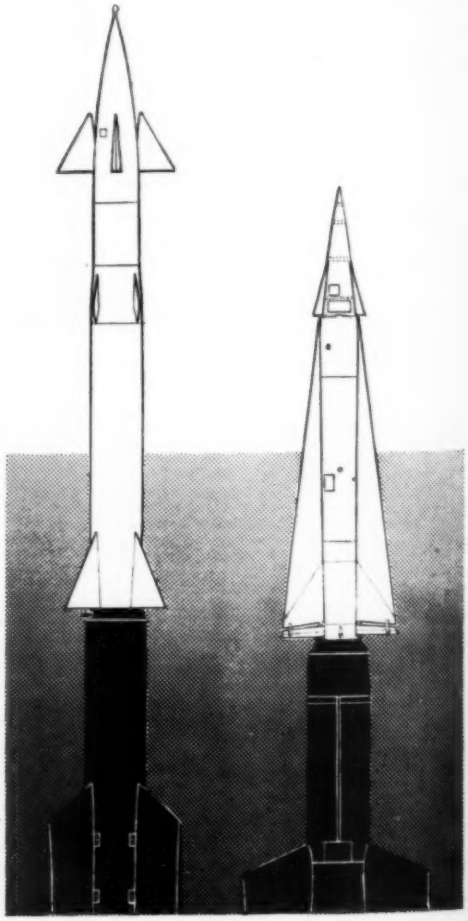
US ARMY, US MARINE CORPS AND ARMIES OF BELGIUM, FRANCE, WEST GERMANY, ITALY AND THE NETHERLANDS

IT was in June 1954 that research and development started on a missile intended to close the altitude gap below the level at which the Nike radars could distinguish targets from ground clutter. A team including the Army Ordnance Corps and Raytheon Manufacturing Co soon elected to use continuous-wave (coherent-pulse Doppler) radar with very high discrimination, and to give the missile a receiver dish in the nose—hence its name, formed from the initial letters of "homing all-the-way killer."

The missile itself is essentially a 14in-diameter tube deep-drawn from steel sheet, containing an Aerojet-General boost/sustainer solid motor, to which are attached the cruciform of low-aspect-ratio wings with trailing-edge controls, and the nose radome. It has never been suggested that Hawk would have a nuclear warhead, but the Army say that it "will be armed with several types of special-purpose warheads in existence today." The complete weapon system can maintain a high rate of fire, and the standard mobile launcher carries three rounds which are automatically loaded by a separate tracked vehicle. Most ground equipment is by Northrop.

The first Hawk battalion was a training unit activated in June 1959. Each battalion normally consists of an HQ, with about 95 officers and men, and four firing batteries. In the continental US the latter have a personnel strength of about 100, and may include from six to 12 triple launchers. In September one battery from the 55th Missile Battalion and another from the 67th were deployed to defend the Panama Canal Zone. In this case each battery has a complement of five officers and 68 men, and is not tied in with the MSQ-18 Missile Monitor electronic environment available in the U.S. Hawk has, incidentally, successfully intercepted a Little John artillery missile.

Following President Eisenhower's assurance three years ago that the US Government would help NATO nations to build American weapons, the decision was taken by the five nations named in the heading to this section to form an international production programme for Hawk in Europe. The co-ordinating company SETEL, formed in Paris for the purpose, organizes five prime contractors: CF Thomson-Houston, France; Finmeccanica, Italy; Telefunken, West Germany; Ateliers de Construction Electrique de Charleroi, Belgium; and Philips, Netherlands. The agreed deployment is: Germany, nine battalions; Italy, four; and Belgium, France and the Netherlands, three each. It has been stated that roughtly $40m of the total cost of $440m will be contributed by MWDP, and the American prime contractor, Raytheon, is providing technical support.



SURFACE - TO - AIR MISSILES: 1, Seacat; 2, Bomarc B; 3, Redeye (twice the scale of the other missiles); 4, Tartar; 5, Hawk; 6, Mauler (provisional); the vertical missiles are (from left) Nike Zeus, Nike Hercules, Nike Ajax, Talos (conventional warhead), Masurca, Terrier 1, Bloodhound Mk 1, Thunderbird Mk 1 and Seaslug Mk 1. The tinted background panel represents a height of 25ft

Masurca

Radar-command missile for surface ships

FRENCH NAVY

MASURCA is the last survivor of the prolific crop of surface-to-air missile programmes which France undertook during the past decade. Its retention is due to its undoubted quality, and to the fact that during extensive work with the Maruca research and training missile most of the many problems posed by ship-to-air weapon systems have already been overcome. Masurca, which may stem from "marine surface contre avions," is a complete system matched to all ships of more than 3,000 tons displacement. The missile itself is stored in the magazine with its tandem boost motor attached, and is fed up to the single or twin launcher in much the same way as Terrier.

The weapon is suspended beneath its launcher, and departs under the thrust of the 1,100lb solid charge of the booster. During the first 3,600ft the missile is unguided, but flies towards the target as a result of the steering of the launcher. After booster burnout, cruise propulsion is provided by an 882lb end-burning solid charge with a length of 98.5in, which is kept continuously fed towards the nozzle by hydraulic pressure. The missile is gathered in the guidance beam and, after computed corrections have been passed to it, is centred 10sec from launch. The ship's radar system then remains locked on to the missile and target, and continuously transmits steering signals to cause the two "blips" to converge. When the range of missile and target is identical a special code in the transmission detonates the warhead.

Prime contractor is the EI de la MN à Ruelle (government arsenal), assisted by numerous industrial firms. From the outset the complete Masurca system has been designed to make minimum demands upon the vessel in which it is installed and to achieve a high rate of fire. It is particularly hoped that the weapon will be effective against targets at very low altitudes. Many of the more critical components of the missile were tested in Marucas before flight tests of Masurca itself commenced last year from land launchers at the Ile du Levant, near Toulon. Tests with the complete shipboard system should by now have started from the surface vessel *Ile d'Oléron*. Masurca is likely to be seen on several of the *Surcouf* escorts, on the *Jeanne d'Arc* helicopter and training carrier (due to commission in 1963) and on a special missile cruiser already under construction for service in 1964.

Mauler

Battlefield air-defence system

US ARMY

ACCORDING to the Department of Defense "Mauler is a proposed highly mobile, self-propelled, high kill probability guided-missile system designed to provide all-weather air defense of forward combat elements of the Army against low-flying aircraft and short-range ballistic missiles and rockets. It is under development by the Army Rocket and Guided Missile Agency." Prime contractor is Convair, who have issued the artist's impression reproduced in our August 19 issue. It depicted 12 missiles carried on the Food Machinery M-113 tracked vehicle provided with four gyro-stabilized Raytheon radar dishes (probably CW). A naval version of Mauler has been unofficially suggested.

Nike Ajax

Radar-command system for deployment from fixed bases

US ARMY (DOMESTIC AND OVERSEAS DEPLOYMENT) AND ARMIES OF FRANCE, ITALY, JAPAN, TURKEY AND WESTERN GERMANY

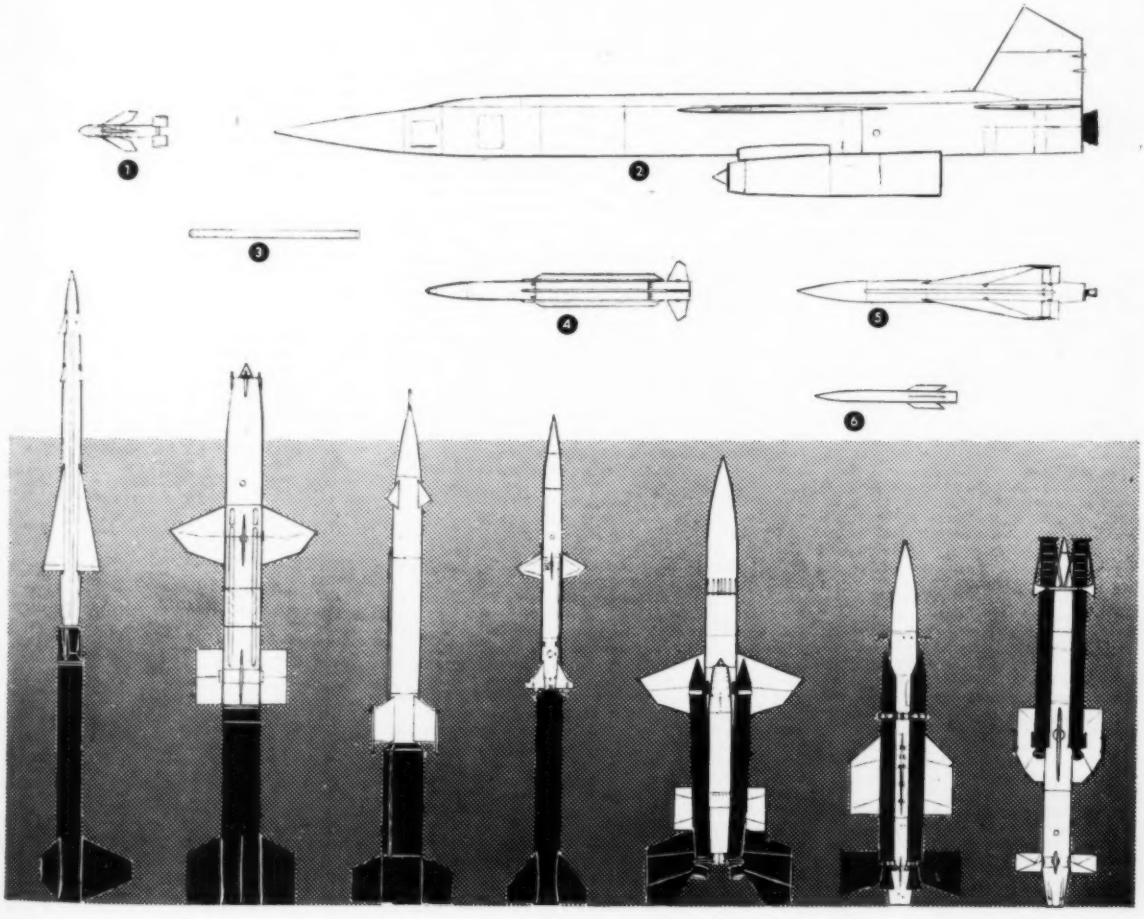
FULL details of this pioneer surface-to-air guided weapon were contained in our 1956 review. The prime contractor, Western Electric, with Bell Telephone Laboratories assisting with guidance and Douglas Aircraft responsible for the missile, evolved a complete system in which radars track the target and missile and a computer translates the difference into steering signals. The US Army have approximately 40 battalions, each consisting of four batteries of nine launchers each. Production ceased in 1958 when more than 20,000 SAM-A-7 Ajax missiles had been delivered. Batteries are now converting to the more effective Hercules.

Nike Hercules

Radar command missile for integration with the existing Nike system

US ARMY

OWING to its command character, the Nike surface-to-air system has proved singularly amenable to improvements in performance. In part this improved performance has stemmed from the introduction of new radars of much enhanced power and discrimination. A further enormous improvement in coverage and lethality is being achieved by replacing the Ajax missile by the SAM-A-25 Hercules. Much larger than Ajax (see scale drawings) it is launched by a four-barrel booster and has



a high-impulse solid sustainer by Thiokol. Manœuvrability has been found to be a substantial improvement over that of Ajax, and the missile can carry either a very large conventional warhead or a nuclear warhead.

The introduction of new GE acquisition and tracking radars is enabling Hercules to intercept tactical missiles. Recently a Hercules destroyed a Corporal, representing an interception problem comparable with that which an ICBM re-entry vehicle sets Zeus. Equally remarkable was the recent destruction of one Hercules by another at a height of 19 miles and a closing speed of roughly M7. There are to be approximately 80 Hercules batteries, each with nine launchers, and a number are operational in Western Germany, Okinawa and Formosa.

Nike Zeus

Radar-guided anti-missile system

US ARMY

HAVING a performance of an order which eclipses that of any other surface-to-air (or, rather, surface-to-space) weapon, Zeus was initiated as a full-scale programme by the US Army in 1957. Although originally in competition with other Army and USAF systems, it is today the only weapon in the Western world known to be under development intended to intercept re-entry vehicles from ICBMs. Its development, handled by the same team—led by Western Electric, Bell Telephone Laboratories and Douglas Aircraft—that has supported the Nike family for 13 years, was charted in our 1958 and 1959 missile reviews, and also in our issues of January 1 and May 20 last.

Overall management of the programme is vested in the Army Rocket and Guided Missile Agency (a section of the Army Ordnance Missile Command), and the substantial appropriations which have been voted have almost matched the magnitude of the development problems. The largest of the latter are the fundamental ones of achieving sufficient warning time and electronic power to detect and track the tiny incoming warhead, plot its future position and fire the Zeus missile to intercept it. Two of the chief electronics subcontractors are Sperry and RCA, both of whom hold large contracts for target-tracking or missile-tracking radars of immense power and discrimination. The scanners for these units will be mounted beneath geodesic radomes fabricated by Goodyear from styrene plastic blocks.

As the drawings suggest, Zeus has a configuration markedly different from that of earlier Nike missiles, and it is also much larger. The weapon is launched by a Thiokol tandem boost motor, rated at 450,000lb at sea level (the highest thrust yet achieved through a single nozzle), which has many times been successfully fired during the past two years. Grand Central Rocket Co first fired the sustainer in May last year, and this motor is noteworthy for its thin walls, high specific impulse and plastics nozzle developed by Douglas. The first test vehicle, of interim configuration (picture, January 1), was launched at White Sands on December 16, 1959. After four further firings, a vehicle more akin to the definitive configuration was launched on April 28.

Operational Zeus emplacements will be located beneath ground level, not in an attempt to harden them but to reduce maintenance problems and ease the difficulty of achieving a climate-free environment. Owing to the confines of the White Sands range, full-range testing will be conducted from a special facility at Point Mugu, and from Kwajalein Island in the Pacific, where elements of a complete Zeus battery are being installed. Missiles from this small atoll should be fired next June against Atlas ICBMs fired from Vandenberg AFB some 4,500 miles to the east. Originally, Jupiter IRBMs launched from Johnston Island were also to have been used. It is particularly hoped that the Atlas targets will be able to dispense decoys, to test the discriminatory powers of the Zeus radars.

The Army Ordnance Missile Command describe the functioning of the system in the following terms. "Within seconds after the approaching ICBM has been picked up by the acquisition radars, a Nike Zeus battery will be automatically assigned to the mission and the missile will be launched. Radars at the launching site will lock-on the hostile missile when it comes within the detection range. The battery computer will then follow the complete action through its radar systems and automatically guide the Zeus missile directly into the path of the oncoming missile. And, at a critical instant, a blast will be triggered, destroying the invading missile warhead. This entire engagement, from detection to destruction of the enemy missile, will take place within 20 minutes, and span activities covering many thousands of miles. The most significant aspect of this defense system is its reliability. The Nike Zeus will function as a fully automated system, free from such mechanical shortcomings and human weaknesses as time-reaction limitations and fatigue."

Redeye

Personal anti-aircraft system

US ARMY AND MARINE CORPS

THIS remarkable little weapon is officially described as "a shoulder-fired, bazooka-type air defense guided missile which will provide the individual forward-area soldier with a defense against low-level aircraft attack." Under a programme managed by the Army Rocket and Guided Missile Agency, Convair's Pomona Division is developing the weapon for use by the Army and Marine Corps. The missile has a boost/sustainer solid motor, and carries an infra-red homing device which must steer by jet deflection. Since it is fired from a tube it could well lead to a very effective anti-armour weapon, with terminal homing and no minimum effective range.

Seacat

Command-guidance weapon for close-range defence of all types of surface ship

ROYAL NAVY, AND NAVIES OF AUSTRALIA, NEW ZEALAND AND SWEDEN

SOME four years ago Short Bros & Harland Ltd started research into the problems of producing a command-guidance anti-aircraft weapon which, as a result of less-ambitious design performance, could be made much smaller, cheaper and less complex than earlier missiles. After preliminary research with the SX-A5 test vehicle the company were awarded a development contract for the Seacat ship-to-air weapon system in April 1958. From the outset it was intended that it should replace guns as the Royal Navy's standard close-range weapon against aircraft. This at once imposed stringent limitations on the weapon system as a whole.

Its wide deployment would have been impossible had not its capital cost, and the difficulty of converting existing ships to take it, been very modest in comparison with previous ship-to-air missiles; moreover, it had to be made compatible with ships down to about 500 tons displacement. Two other factors are that the weapon system had to have a very brief reaction time, almost tantamount to the ideal of "instant readiness," and a rate of fire sufficient to enable numerous targets to be engaged in quick succession.

Seacat itself is much smaller than the majority of anti-aircraft missiles, and instead of a jettisonable boost system has a two-stage internal solid motor, the initial charge giving very high thrust to ensure a clean launch at all angles of elevation. Around the motor is a cruciform of fixed fins indexed at 45° to the cruciform of swept moving wings disposed around the square-section forebody. The installation in a ship comprises one or more quadruple launchers, and a director turret. The latter takes the form of a revolving emplacement containing the shipboard part of the radio guidance system, apart from the aerial, and around it is a circular platform on which stands the control officer.

On receipt of the bearing of incoming hostile aircraft which may have escaped other defence systems of greater range, the control officer swings the director to face the target. Sitting in the director is an aimer, whose task it is to pick up the target in a pair of powerful binoculars carried on a tubular cross-structure on which are also mounted a firing pistol-grip and a control stick. An electro-hydraulic linkage between the director and launcher maintains the latter in exact alignment with the aimer's binoculars.

When the aimer signals that he has a target in view the control officer fires a missile. As soon as the Seacat has left the launcher it comes into the field of vision of the aimer, who thereafter keeps both missile and target in view. His job is to drive the missile and target into coincidence. He does this by imparting commands to climb, dive, go left and go right from the pendulous control in his right hand, which governs a coded radio signal sent out from the transmitter aerial in the centre of the launcher. Doubtless the missile is provided with tracking flares, and with a proximity fuze.

Since four rounds are carried on each launcher, four targets can be engaged before reloading. When the launcher is empty it is automatically elevated to 90°. Each missile platform in turn is then tilted out through 90° to accept a Seacat, protected by its rigid storage envelope, brought in manually and slid along the guide rails. A trained crew can reload the launcher in less than 40sec. The complete weapon system is coming into large-scale production for the Royal Navy, has been purchased by Australia, New Zealand and Sweden, and is being evaluated by Western Germany.

Seaslug

Beam-riding missile for surface ships

ROYAL NAVY

A LENGTHY account of the development of the Royal Navy's principal anti-aircraft guided weapon was contained in our issue of November 21, 1958. The chief contractor is Sir W. G. Armstrong Whitworth Aircraft, assisted by GEC for guidance and Sperry for control. As finally developed, Seaslug Mk 1 is a highly refined weapon system capable of being fitted into any surface ship with a displacement of more than about 3,000 tons and able to maintain an appreciable rate of fire against targets at considerable ranges. Total floor space required is roughly 8,000 sq ft. Rounds are supplied in environment-proof containers and stored ready to fire in magazines below decks from which they are fed by hydraulic handling gear up to the lattice launcher (which may be single, twin or triple).

A characteristic of the missile is its very modest overall envelope size, resulting from mounting the boosts on the forebody, so that they do not need stabilizing fins, and squaring-off the boost noses in line with the nose of the missile. After the four boosts have been jettisoned, the missile is gathered in the guidance beam, stabilized in roll and propelled by the internal solid sustainer. Guidance and control packages are mounted in pressurized cases occupying 120° segments of the forebody, and in the production weapon the guidance receiver is re-arranged and incorporates printed circuits in the sub-units and interconnecting cable forms. As the missile flies up the pencil beam from the ship's tracking radar its departure from the centre of the beam is sensed as an error-signal, which is fed into the control system to steer the missile back to the centre of the beam by movement of the rectangular tail fins.

First ships to be armed with Seaslug will be the County class (*Flight*, 24 June, 1960) with a displacement of a little over 5,000 tons and carrying an automatically served twin launcher on the quarterdeck (plus Seacat launchers amidships). Some hundreds of test firings from shore bases and afloat have yielded excellent results, and six kills with six rounds were recently recorded during trials against target drones.

Soviet missiles

Radar-command weapon for deployment from mobile launchers

RED ARMY (PVO)

ONLY one type of Soviet surface-to-air missile has been publicly seen. Unofficially dubbed the "M-2" in the West, it was first displayed in Moscow in November 1957 and, on a revised launcher, made a further appearance earlier this year. Most observers have calculated its performance to be comparable in most respects with that of Nike Ajax, and it appears certain that the PVO (air-defence force) is now receiving weapons of a more advanced nature. American publications have frequently pub-

SURFACE-TO-AIR MISSILES

	Range (n.m.)	Altitude limits (ft)	Launch weight (lb)		Length (ft)		Body D (in)	Span (in)	Mach no
			+ boosts	without	+ boosts	without			
Bloodhound I ...	60+	—	—	—	25.25	22.2	21.5	112.5	—
IM-99A Bomarc ...	200	/68,000+	15,000	n.a.	49	n.a.	34.6	218	2.7
IM-99B Bomarc ...	440	0/100,000	—	n.a.	49	n.a.	34.6	218	3.8
Contraves RSD ...	18	—	n.a.	882	n.a.	19.75	15.75	53	2.4
Hawk	19.5	10/60,000	n.a.	1,275	n.a.	16.8	14	48	2+
Masurca	13.5	/70,000	3,198	1,653	28.2	19.1	—	55.1	2.5
Nike Ajax	26	5,000/60,000	2,300	1,100	34.9	21	12	53	2.5
Nike Hercules ...	74+	/150,000+	10,000	5,100	39.7	26.8	31.5	90	3.35
Nike Zeus	200+	n.a.	40,000?	—	63	—	60	—	4+
Redeye	3?	10/5,000?	n.a.	20	n.a.	4	3	n.a.	2+
Seacat	—	0/10,000?	n.a.	—	n.a.	4.82	7.5	25.6	1+
Seaslug	—	—	—	—	19.7	19.7	16.1	56.6	—
Talos	65+	90,000+	7,000	3,100	30.5	20.5	30	112	2.5
Tartar	9+	1,000/40,000	n.a.	1,500	n.a.	15	13	20	2.5+
Terrier	10.5	60,000	2,900	1,100	26.6	14.8	13	46	2.5
Terrier (Advanced)	20+	—	5,000	1,500	29.5	14.8	13	20	3
Thunderbird ...	20+	—	—	—	21	21	21	63	—

lished reports, from unstated sources, purporting to outline the disposition of such weapons, in some cases siting them around so-called ICBM bases.

At the same time, there appears to be extreme American reluctance to accept the Russian statement that such a missile was responsible for the failure of the most notorious Lockheed U-2 to complete its mission on May 1. It was stated by the Russians that an anti-aircraft battery near Sverdlovsk obtained an air burst below the tail of the U-2 with the first round fired. Shortly thereafter, Marshal Malinovsky, Minister of Defence, claimed "Our rockets are able to hit targets not only at an altitude of 20,000m, but much higher . . . you do not have a plane with a ceiling that could not be reached by our rockets."

Talos

Long-range defence system for large surface ships

US NAVY

REPRESENTING the long-range offshoot of the original Bumblebee programme of 1949, the SAM-N-6 Talos system is extensive and expensive but provides superb protection to any large surface ship out to a radius of about 70 miles. The missile is basically a 30in tube, provided with rear fins and a cruciform of moving wings and containing an integral ramjet burning a mixture of kerosine and naphtha fed by turbopump from annular tankage. The missile is launched by a large tandem booster after being automatically selected, inspected and delivered to the launcher. One type of Talos has a nuclear warhead, and is guided by riding a radar beam to the vicinity of the target. The other type has a conventional warhead, arranged as a pre-fragmentation or rod type assembly surrounding the ramjet duct. To improve its lethality the h.e. missile has semi-active terminal homing, associated with the powerful shipborne SPG-49 illuminating radar, the ring of aerials and pitot probes around the nose intake readily distinguishing it from its nuclear counterpart.

First vessel in service with the Talos is the cruiser *Galveston*, which commissioned in May 1958 and fired the first operational Talos at sea on February 24, 1959. Her twin launcher is said to be capable of firing a missile every 30sec for long periods. Present plans call for Talos to be installed in six more cruisers before the spring of 1962. Extensions of the system are referred to under the name Typhon.

Tartar

Defensive system for small ships

US NAVY

ALSO stemming from the original Bumblebee programme managed by the Johns Hopkins Applied Physics Laboratory, Tartar is closely related to Terrier 2, the airframes of the two weapons being almost identical. An obvious difference is that Tartar has a new Aerojet-General boost/sustainer motor, so that a tandem booster can be dispensed with. This significantly reduces the envelope size and makes the weapon amenable to storage and handling in more confined spaces. Accordingly Tartar can either replace 5in guns in secondary batteries aboard large ships or it can be installed in destroyers and similar vessels.

Like the Terrier family, Tartar is produced by Convair's Pomona Division. Apart from the fact that the system contractor is Raytheon, no details of the guidance have been divulged; but it seems highly likely that semi-active radar homing is used, employing CW signals similar in character to those of Hawk (Tartar certainly has a receiver dish aerial protected by a nose radome.) The missile is scheduled to be deployed aboard three cruisers and either 18 or 21 destroyers. The Japanese Maritime Self-Defence Force have ordered 42 Tartars for installation aboard destroyers. Test firings from USS *Norton Sound* have been in hand for 18 months.

Terrier

Defensive system for large surface ships or mobile land forces

US NAVY AND MARINE CORPS

AFTER seven years of R & D by the Applied Physics Laboratory of Johns Hopkins University under a Bureau of Ordnance contract placed in 1949, Terrier 1 (SAM-N-7) was released for service as a ship-to-air system in 1956. A slight variation incorporates mobile ground launchers for use by USMC detachments. Terrier 1 is operational aboard three cruisers, a destroyer and a frigate, but has been superseded by an advanced derivative.

Terrier 2. Also known as Advanced Terrier, this natural outgrowth has greatly increased effectiveness. The only official description speaks of "improved guidance features providing substantial improvements in coverage." The missile itself is completely revised aerodynamically, and has wings of exceedingly low aspect ratio and movable tail controls, Terrier 1 having moving wings and fixed tail fins. The missile is superficially similar to Tartar, depicted in the scale drawings. After launch by a tandem solid booster much larger than that of Terrier 1, the missile flies on a solid sustainer of high specific impulse. It has been unofficially reported that the beam-riding guidance common to both types of Terrier is in the new missile supplemented by a terminal homing system. Flight performance has been considerably increased and very large orders are in hand at the Naval Industrial Reserve Ordnance Plant operated by Convair at Pomona. Terrier 2 is in service aboard the new frigate *Dewey*, and is being deployed aboard the nuclear-powered carrier *Enterprise*, two conventional carriers, the nuclear-powered cruiser *Long Beach*, three conventional cruisers, the nuclear-powered frigate *Bainbridge*, and 18 conventional frigates additional to *Dewey*. It will be employed by the US Marine Corps in a system including portable radars, launchers and loaders.

Thunderbird

Semi-active radar homing system for mobile field use

BRITISH ARMY

DURING the past ten years English Electric have been progressively developing Thunderbird against Government contracts. Under the code name Red Shoes work began as a general investigation of semi-active homing missiles with liquid-propellant engines and cruciforms of wings and rear control surfaces. As was noted in our extensive description of September 25, 1959, the company then redesigned the hardware to turn it into an operational anti-aircraft system capable of being deployed by modern mobile armies. Maintenance by replacement was accepted to ensure constant readiness, and the missile itself was arranged as a synthesis of discrete subassemblies so that extensions in performance could be introduced by modifying one part at a time. From front to rear the missile comprises a pointed radome covering the receiver dish, the guidance bay, the warhead and proximity-fuze system, the solid-propellant sustainer motor in line with the wings, and the control system, a.p.u. and control surfaces all disposed around the motor tube.

On arrival at a user battalion, Thunderbirds are packaged in shockproof containers, from which they are withdrawn at a Field Assembly and Test Point, where they are assembled and exhaustively tested. Warhead and four wrap-round boost motors are then added, and the missile, already mounted on its launcher elevating frame, is then towed out to the appropriate emplacement and slid on to the launcher base. Supporting the missile are the conventional generation, control and test equipments, together with a tactical radar and a tracking and illuminating radar, all portions of the system being mounted on standard British Army vehicles. Many hundreds of rounds were fired during the development programme. A training school (*Flight*, June 5, 1959) is located at Manorbier and two regiments of the Royal Artillery are operational.

Early last year it was announced that Thunderbird was being developed to achieve substantial increases in performance. Precise details of Thunderbird 2 may not be divulged beyond the following: CW radar is employed, to increase resistance to jamming and improve discrimination against low-level targets; flight performance of the missile has been considerably increased; engineering details of the missile have been refined, and advantage has been taken of the opportunity to introduce later techniques; completely new TI radars are employed, and the launcher has been modified to achieve optimum compatibility with the CW guidance; and, instead of mounting on prime movers, many portions of the Thunderbird 2 weapon system are carried on pallets or lightweight trailers to make the entire system easily air-portable.

Typhon

Advanced ship-to-air system

US NAVY

ACCORDING to the Department of Defense "The Typhon weapon system will be the Navy's surface-to-air missile system of the future. It will take advantage of as many advanced-state-of-the-art improvements for its components as are available. To fully utilize the capabilities of the system for providing anti-air warfare protection to the fleet will require use of two missiles, Typhon long range and Typhon medium range. The name Typhon System has superseded the designation Advanced Weapon System which referred to improvement programmes for Talos and Tartar missiles. Super-Talos has been renamed Long-Range Typhon and Super-Tartar is redesignated Medium-Range Typhon." Prime contractor is JHU/APL, propulsion will be by solid booster and ramjet sustainer and the warhead will be conventional. An unofficial report states that Westinghouse have part of the responsibility, and that the Typhon system will be installed on all types of surface craft, including quite small hydrofoils.

Air-to-Air

Dassault Mirage IIIA carrying Matra R.530 on centreline pylon

Eagle

Long-range high-performance air-to-air missile.

US NAVY

SINCE 1957 the US Navy has been intensively investigating a radically new method of intercepting hostile aircraft. At present ships at sea can defend themselves out to a distance of rather more than 60 miles (the extreme range of Talos), and the only method of destroying an aeroplane at a greater distance is to fly an intercepter out to it. The intercepter might well be armed with guided missiles, but the latter would be used only to effect the kill, and would not have a range greater than about five miles. The new concept is to design an air-to-air missile which can accomplish the complete interception by itself. It is designated AAM-N-10 Eagle.

Such a concept naturally can be met only by a relatively large missile with a very high performance, and a cost (with nuclear warhead) rivalling that of many fighter aircraft. Conversely, the parent aircraft need not have a particularly high performance, and its design can be weighted heavily in favour of maximum lifting ability and endurance. In fact, although existing US Navy bombers, attack aircraft, ASW machines and transports might well have been modified to launch the new weapon, it was finally decided, a little over three years ago, to start with a clean sheet of paper and to place prime contracts for a complete weapon system involving both the new missile and an *ad hoc* aeroplane to carry and launch it.

During 1957 the draft requirement was put out to industry, and the resulting intense competition involved no fewer than 16 companies for the missile alone. The prime responsibility for missile systems management was placed with Bendix Systems Division at Ann Arbor, Mich, whose submission had been made in association with Grumman Aircraft Engineering Corp. As the major subcontractor, Grumman are responsible for the missile airframe, propulsion-system integration and ground-handling equipment. To carry the missile, the Navy drafted a specification for an aeroplane in the 60,000lb class, able to lift three Eagles under each wing and having a "loiter" endurance of approximately 10hr. After a protracted competition, the contract for the Missileer was placed with Douglas Aircraft early in 1960. The aircraft is to be powered by two Pratt and Whitney TF30 (JTF8D) turbofans, each of about 10,000lb thrust, and will have a design Mach number of about 0.75.

Operating from a carrier, the Missileer will fly out to a standing patrol between 100 and 150 miles from the fleet, at an altitude of 35,000ft. At the time of writing it is not yet known whether detection and tracking of the target is accomplished by the Missileer or by its missiles; the aircraft will be fitted with a radar fire-control essentially similar to that of the F4H-1, but the Navy have stressed that the "entire burden" of effecting the interception is transferred to the missile.

To this end, Eagle has a lock-on cruise and terminal homing radar guidance system, the main contractors for which are Westinghouse Air Arm Division (airborne radar), Goodyear Aircraft (nose radome), Litton Industries (airborne tactical computer), Sanders Associates (target seeker equipment), and Bendix Research Laboratories (guidance equipment). Range of Eagle is described as "up to 100 miles from the point of launch"; the weapon is designed to fly at altitudes up to 100,000ft, and its flight speed of M4 enables it to intercept targets travelling at the same speed. Propulsion is provided by Aerojet-General rocket engines, suggesting two-stage propulsion, and AiResearch, Dunlap Associates and Bendix Pacific Division are respectively responsible for missile a.p.u., human factors and missile assembly and testing. A clue to inventory procurement is provided by the fact that total Missileer/Eagle cost over the next "several years" is put at $3,400m; the present Douglas contract is for 120 aircraft, costing about $600m.

Falcon

A family of air-to-air missiles with semi-active radar or IR homing guidance and embodying progressive improvements

US AIR FORCE

A BRIEF history of the development of the GAR-1 Falcon was contained in our 1957 review. The original Project Dragonfly was conceived by Hughes Aircraft and the USAF at Culver City in 1947, and production of the GAR-1 started at the *ad hoc* plant in Tucson in 1954.

GAR-1 The original GAR-1 set the pattern for the family, with a light-alloy/reinforced-plastics airframe with acute-delta wings and trailing-edge control surfaces. The solid-propellant motor imparts an acceleration of 48g at launching. All members of the GAR-1 family can approach their target from any angle. Guidance is semi-active, the target being illuminated by the radar of the launch aircraft and the seeker dish in the nose of the missile homing on to the reflected radiation. After delivery of about 4,000 GAR-1s Hughes progressed to the GAR-1D, with larger control surfaces carried well behind the wing. Between 1956 and 1959 approximately 12,000 GAR-1Ds were delivered, almost half the total Falcon production. These early variants are in service with the USAF Air Defense Command Squadrons equipped with the F-89H, F-101B and F-102A. Both the GAR-1 and -1D are 78in long, have a body diameter of 6.4in, span of 20in and weight of 121lb.

GAR-2 This family differs from the GAR-1 series chiefly in having a new guidance system. From 1954 Hughes had been developing a Falcon with infra-red guidance, and the first variant to go into production was the GAR-2. Distinguished from the radar-guided GAR-1D chiefly by virtue of its glass nose, it was first delivered in the summer of 1956. It has since been customary to carry a mixed load of radar and IR-homing Falcons in order to give pilots the choice of using whichever type is best suited to the prevailing tactical and weather condition. In February 1957 production switched to the GAR-2A, designed for operation over a wider band of ambient temperatures, and production was terminated after delivery of 9,500 units.

GAR-3 First of the Super Falcons, the GAR-3 was introduced in 1958 to meet the requirements of the F-106A. Its improvements include an advanced semi-active radar guidance system, a motor with extended burning time, a pointed nosecone of a new material, wings of revised profile and plan-form and a more

In promoting the Northrop N-156F as the delivery vehicle for the Rapiere system, Northrop emphasize that it can carry a remarkable variety of weapons. Air-to-air missiles in this illustration include: A, Sidewinders; B, Sparrow 3s; C, GAR-1D Falcons; D, GAR-3A Falcons; E, Zuni 5in folding-fin rockets; F, 2.75in folding-fin rockets; G, Nord AA.25s or AS.25s

powerful warhead. As a result it can be launched at higher speed than its predecessors, and has increased flight speed, greater range and improved altitude capability. When about 300 GAR-3s had been delivered, in the summer of 1959, Hughes switched to the GAR-3A. The main improvements in this version are the introduction of an entirely new rocket motor, with boost and sustainer charges, which operates with extreme reliability over a further extended range of ambient temperatures, coupled with a largely new guidance system which confers enhanced accuracy and greater ability to discriminate between countermeasures and the true target. Superficially the -3A can be distinguished by the fact that the forward portion of the body is covered by a white, moisture-sealing sleeve and that the nosecone is tipped by a four-inch metal probe stated to improve the missile's aerodynamic qualities. More than 800 of this version had been delivered by September 21.

GAR-4 There is no GAR-4 as such, the IR counterpart of the GAR-3A being the GAR-4A. This weapon is equipped with an entirely new seeker cell, claimed to lock-on "to smaller targets at greater ranges than ever before possible." Introduced in 1959 the GAR-4A is carried by the F-106 in mixed loads with the GAR-3A.

GAR-11 Introduced in 1960, for service with the F-102A, the GAR-11 Nuclear Falcon is the first air-to-air guided weapon to go into service with a nuclear warhead. It employs the same guidance and control components as the GAR-1D, and is designed to be carried by the F-102 without modification to either the launching arms or the intercepter fire-control. Radar guidanee was chosen for the Nuclear Falcon for a number of reasons, the chief of which is that it enables attacks to be made from head-on and in adverse weather conditions. Difficulties associated with the high rate of closure between the intercepter and its target (and the nuclear blast) are overcome by the fact that the GAR-11 will lock-on to a target at least 30° from dead ahead. Owing to its much greater weight and increased drag GAR-11 has a rather lower performance than earlier Falcons, and later nuclear versions may be anticipated.

Firestreak

IR-homing missile

ROYAL AIR FORCE AND ROYAL NAVY

UNDER the code name of Blue Jay this high-performance weapon system has been under development by de Havilland Propellers Ltd since 1951, and it is today in full squadron service with Javelins of RAF Fighter Command and Sea Vixens of the Royal Navy. Firestreaks will also form the primary armament of most of the Lightning intercepters of the RAF. A history of its early development was published in our issue of May 3, 1957, and a full description and cutaway drawing will be found in our issue dated February 26 of this year.

Equipment carried in the parent aircraft consists of a hydraulically driven alternator, controller and condenser, a launch sequence unit, fire-control power unit and (sometimes) a slaving unit. On the front of the missile is a miniature reflecting telescope protected by the conical nose of the missile which is fabricated from glass with optimum optical qualities. This telescope picks up the infra-red (heat) radiation emitted by a target aircraft, magnifies it and passes it to a sensitive cell in the guidance homing head on which the telescope is mounted. After processing by a potted guidance electronics pack and a similar slab of control electronics, the resulting signals are used to steer the weapon, the tail controls being actuated by control rods running along the body on either side of each pair of wings. Many of the airborne services are pneumatic, served from a bottle surrounding the blast tube from the solid internal motor. The large warhead likewise surrounds the blast tube, in this case forward of the control surfaces. It is detonated by a sensitive proximity-fuze system involving front and rear window assemblies and an electronics pack. After receipt by a squadron, the missile is assembled and tested and may then be launched at any time within 90 days without further testing.

GAR-9

Long-range intercepter missile

US AIR FORCE

WHEN the contract for the F-108 Rapier intercepter was cancelled, its ASG-18 fire control and GAR-9 missile continued to be funded at a reduced rate. Stemming from the Falcon family, this high-performance missile may find applications on other aircraft.

Genie

Unguided rocket with nuclear warhead

US AIR FORCE

OWING to the fact that the lethal radius of its warhead is at least 1,000ft, the MB-1 Genie has no guidance system but is merely corrected against gravity-drop by flip-open fins. It is directed against the target either by GCI or by using the radar of the launch aircraft to point the latter in the right direction. The missile was first fired over the AEC Nevada test site in the summer of 1957. It went into large-scale production by Douglas Aircraft a year later and is now widely deployed in squadrons equipped with the F-89J, F-101B and F-106. It can be carried and launched by the F-104, and unofficial reports state that it is to be matched to the Lightning intercepter of RAF Fighter Command. A non-nuclear training version is in use, and a guided variant is under development.

Matra R.511

Semi-active radar homing missile

FRENCH AIR FORCE

UNDER development by the Société Matra since 1951, this twist-and-steer weapon is in limited production for deployment as an interim weapon to squadrons equipped with the Vautour. Numerous test firings have taken place from a wide variety of aircraft, but owing to limitations in its operational performance its development has been terminated. Fuller details were given in our August 19 issue.

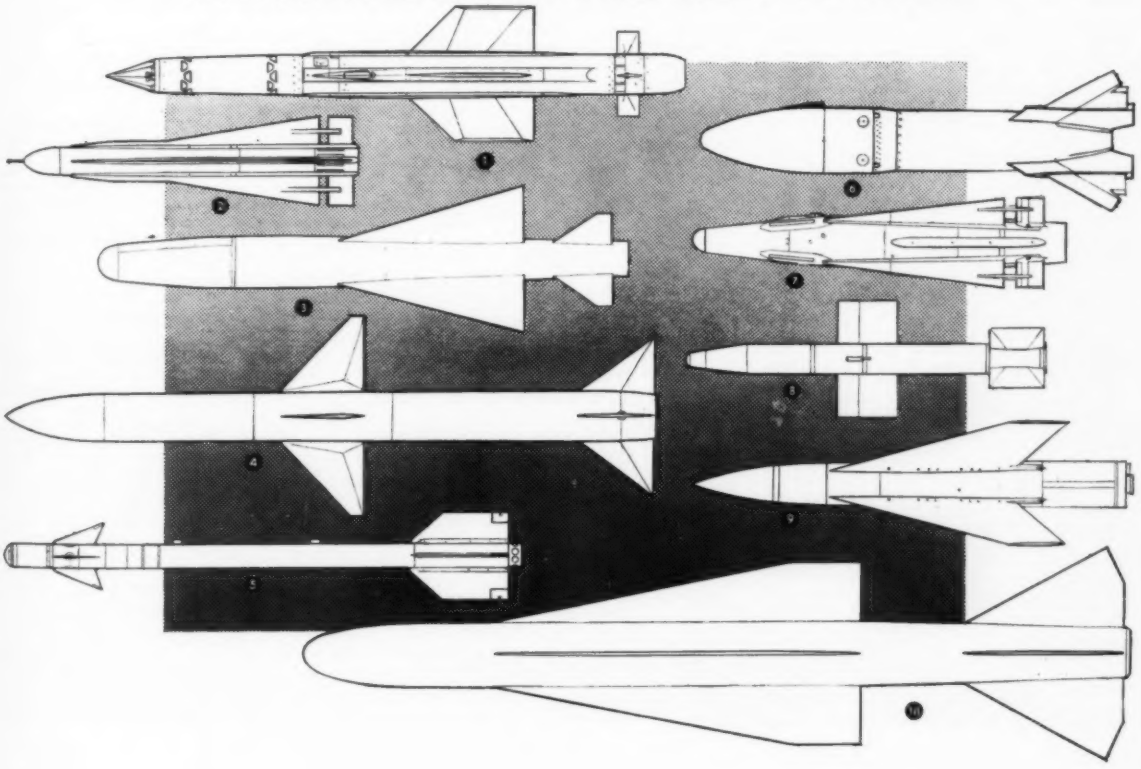
Matra R.530

Semi-active radar homing missile

FRENCH AIR FORCE

COMPARED with previous French air-to-air weapons, the R.530 is rather larger, has a much higher performance and is operationally considerably more attractive. Matra have abandoned the twist-and-steer geometry in favour of

AIR-TO-AIR MISSILES: 1, Firestreak; 2, GAR-4A Falcon; 3, Matra R.530; 4, Sparrow 3; 5, Sidewinder 1A; 6, Genie; 7, GAR-11 Nuclear Falcon; 8, Sispre C-7; 9, Nord AA.20; 10, Eagle. The tinted background panel represents a width of 15ft



AIR-TO-AIR MISSILES

	Launch wt (lb)	Length (in)	Body D (in)	Span (in)	Range (n.m.)	Altitude peak (ft)	Mach number	Warhead
AAM-N-10 Eagle	2,000	180	—	—	87	100,000	4	N (10kT?)
GAR-1D Falcon	121	78	6.4	20	4.5	50,000	2+	20lb?
GAR-2A Falcon	120.5	79.5	6.4	20	4.5+	50,000	2+	20lb?
GAR-3A Falcon	150	86	6.6	24	6+	70,000	3	40lb?
GAR-4A Falcon	145	81	6.6	24	6+	75,000	3	40lb?
GAR-11 Nuclear Falcon	203	84	11	20	4?	—	2	N (2kT?)
Firestreak	300	125	8.67	29.4	4+	—	2+	50lb?
MB-1 Genie	900	114.9	17.4	—	2.5	50,000+	3	N (2kT?)
Matra R.511	397	122	10.24	39.4	4.1	59,000	1.8	55lb
Matra R.530	—	—	—	—	—	—	2+	60lb?
Nord AA.20 (5103)	293	102.4	9.84	31.5	2.2	50,000?	1.7	51lb
Nord AA.25 (5104)	298	102.4	9.84	31.5	3	—	1.7	51lb
Red Top	—	—	—	—	7	—	3+	68lb
Sidewinder 1A	155	113	4.8	20	2+*	50,000+	2.5	10lb
Sispre C-7	143	77	6.3	25	6.2	—	1.9	55lb
Sparrow 3	380	144	8.5	39	5+	50,000+	2.3+	60lb?

* Reduced to about 3,500ft at sea level.

cruciforms of delta wings and rear-mounted controls indexed in line. During the development of the earlier R.510/511 series Matra finally chose semi-active radar homing (actually a semi-passive optical system) after having previously employed IR-homing guidance using a PbS seeker cell. The company are currently investigating both IR-homing and semi-active radar guidance for the R.530, but it is unofficially suggested that the heat-homer will not see operational service. Propulsion is by an internal solid motor with boost and sustainer charges.

No details of the flight-test programme are available, beyond the facts that a "considerable" number of rounds have been fired and that development is so far satisfactory. It is expected that this missile will become the standard French air-to-air weapon at the beginning of 1962, the Vautour being equipped to carry four and the Mirage being able to carry either one or three.

Nord AA.20

Radio-command missile

FRENCH AIR FORCE AND FRENCH NAVY

IN 1953 the SFECMAS/Nord Group were awarded a contract for an air-to-air weapon system which, by making minimum state-of-the-art demands, could be expected to enter operational service at a relatively early date. In our analysis of the weapon on July 15 we wrote "Although the AA.20 was from the outset intended to be a fully effective operational weapon, it was generally regarded as an interim missile pending development of the ultimate Matra 530 series, and so was never intended to be an 'all-can-do' weapon. On the contrary, by setting fairly modest design targets, and in particular by adopting command guidance, the problems of development were minimized, operational delivery hastened and the versatility and flexibility of the final weapon system increased. As a result the AA.20 cannot be used at night or in bad weather, although developments overcome this limitation. On the other hand, as long as the target can be seen the missile can be launched against it, so that attacks can be made from any quarter and not only from astern or on a collision course."

Basing their work on the great experience gained with subsonic anti-tank missiles, Nord adopted a command-guidance system employing visual alignment of the missile and target and steering commands imparted by a joystick-type control. The command signals are transmitted by a coded radio link and used to govern the vibration of four solenoid-biassed interrupter blades pivoted around the solid-propellant sustainer nozzle. Boost propulsion is provided by a separate charge exhausting through twin nozzles flanking that of the sustainer. The four highly swept wings cause the weapon to roll, so that a single cordite-driven gyro can be used as a reference to pass pitch and yaw demands to the jet spoilers. The sustainer is virtually smokeless, and in clear weather it is not difficult for the pilot of the launching aircraft to drive the missile and target into coincidence (while at the same time flying his own aircraft on a completely independent path). When the missile is 50ft from its target the proximity fuse, "looking" through an annular window around the forebody, explodes the pre-fragmentation warhead, which weighs 50lb and contains 11lb of explosive (half Hexogen, half Tolite).

As the Nord 5103 Type M2RT the complete weapon system went into production in 1956 at Chatillon, except for motors and warheads which are made at Gâtines. Since the AA.20 system needs no airborne radar it can readily be installed in any aircraft equipped with a radar-ranging gunsight, and is widely used on the Mystère IVA, Super Mystère B2, Mirage III, Vautour, Etendard IVM and Aquilon. Pilot training requires no live firings, apart from two or three SS.11s—with similar controls—launched from a Magister.

Nord AA.25

Radar-command missile

FRENCH AIR FORCE

SUPERFICIALLY the missile portion of this weapon system, now in pre-production at Chatillon as the Nord 5104, is difficult to distinguish from the AA.20 Type 5103. Operationally it overcomes the most severe limitations of the earlier system, since the pilot of the launching aircraft no longer has to impart steering commands or even keep the missile in view. Instead, the fire-control radar continuously monitors the bearing and range of the target and missile and, after processing in a computer, transmits command signals to make the two sets of readings converge. The AA.25 system can thus be used at night or in cloud, against a target anywhere in the forward hemisphere of the launching aircraft.

The AA.25 system was originally developed to be compatible with the CSF Cyrano fire-control of the Mirage IIIC, and will be used in this aircraft with either this radar or Ferranti Airpass 2. The 5104 missile is also included by Northrop in the Rapiere (N-156F) weapon system, matched with the Hughes Taran fire-control.

Red Top

BEYOND the fact that the experience of de Havilland Propellers Ltd is being applied to the development of "more advanced air-to-air missiles with the improved performance needed to keep abreast of increases in target speed and operating altitude," nothing whatever can be divulged on this project (even the name has not been officially released). In our 1959 review we published a report by the American publication *Aviation Daily*, stating that Red Top will carry a 68lb conventional warhead over a range of 14,000yd, having IR guidance "using a cooled lead telluride cell receiving in a 4 to 5 micro range."

Sidewinder

IR-homing missile

US NAVY, US AIR FORCE, US MARINE CORPS, AIR FORCES OF AUSTRALIA, JAPAN, NATIONALIST CHINA, PHILIPPINES, SWEDEN, SPAIN AND NINE NATO COUNTRIES, AND ROYAL CANADIAN NAVY

LONGER than that of any other missile, the list of users above is a tribute to Sidewinder's proven effectiveness—during the Quemoy crisis two years ago it became the first air-to-air guided weapon to destroy aircraft in actual combat—and to its ready adaptability to existing fighter aircraft. As was noted in our 1957 review, it was conceived at the Naval Ordnance Test Station at China Lake, and was developed jointly by that establishment and by Philco, GE being brought in in 1957 as an additional prime. From front to rear the missile consists of sections of light-alloy tube containing a heat-seeking head, control unit and fins, distributed warheads, 75in motor and large tail fins carrying slipstream-driven stabilizing gyro wheels.

All Sidewinders currently in service are of the SW-1A model, of which approximately 40,000 have been delivered. Its naval and USAF designations are AAM-N-7 and GAR-8, respectively, and it has been in service since mid-1956. Production in Europe is in hand in Germany by Bodenseewerk Perkin-Elmer, whose first order is unofficially reported to be for 5,000 rounds. Now in an advanced state of development at the NOTS is the SW-1C, described as a second-generation weapon. Prime contractor is Philco, and its improvements are officially described as yielding "higher speed and greater range." According to the American journal *Missiles & Rockets*, SW-1C will have "switchable IR and radar homing warheads."

Sispre C-7

IR-homing missile

ITALIAN AIR FORCE

HAVING been four years under development by the Societa Italiana Sviluppo Propulsione a Reazione, formed jointly by Fiat and Finmeccanica, C-7 is now in pre-production and is expected to be operationally deployed from Italian Sabres and G.91s next year. Propelled by a boost/sustainer motor, the missile has a cruciform of fins but only one pair of wings, both of which pivot to manœuvre the weapon by twist-and-steer. The rounded glass nose protects an infra-red seeker, which the company claim to have exceptional sensitivity and the ability to accommodate "big angular errors in firing." A particular feature of the missile is that it is stated to make minimum demands in such matters as production tooling, personnel training and aircraft conversion.

Sparrow

All-weather radar homing missile

US NAVY AND MARINE CORPS

A history of the original project Hot Shot, leading to Sparrow 1, was contained in our 1957 review. In that year Sparrow 1 was phased out of production at the Sperry-Farragut Plant and was replaced by Sparrow 3, developed by a team led by Raytheon. Compared with the earlier weapon Sparrow 3 has a larger body, wings of increased area, a receiver dish under the nose radome for homing on to radiation reflected from the target, and considerably increased lethality. The first production series, totalling many thousands of rounds, incorporate an Aerojet solid motor, and have been operational with both Atlantic and Pacific fleets since August 1958. Current production is powered by one of the Guardian series of pre-packaged liquid rockets by the Reaction Motors Division of Thiokol. The new propulsion system can be stored at instant readiness for what is officially described as "an indefinite period," and it gives the Sparrow 3 a higher performance. The improved missile is carried by the McDonnell F4H-1 Phantom 2.

Anti-tank

Bantam

Light infantry weapon

SWEDISH ARMY

DEVELOPED by Aktiebolaget Bofore as a private venture, Bantam was designed for deployment by infantry operating in adverse terrain at temperatures well below freezing. Accordingly the missile is relatively small and light—it is perhaps the lightest guided weapon in the world—and performance and killing power have had to be slightly sacrificed. Much of the airframe is of reinforced plastics, and the four wings fold at mid-span to fit a slender carrying box. The missile can, in fact, be launched directly from its box, and conical camber on the wing leading edges first unfolds the wings and then rolls the missile. The wire signals are passed to a transistorized guidance package which biasses the trembling of trailing-edge spoilers. Flight trials have been in hand for at least two years.

Bolkow 810

Wire-guided missile for infantry

WEST GERMAN ARMY AND (EVALUATION) US MARINE CORPS

KNOWN until late 1958 as Cobra, the Type 810 was designed by Bölkow-Entwicklungen as a replacement for the SS.10. It is lighter and smaller than the pioneer French missile, and has a velocity control system which has been rationally and painstakingly thought out. An infantryman can very easily carry a complete round in a foamed-plastics container, requiring only assembly of the missile and warhead. Unusual features are that the tips of the moulded wings are thickened and rounded so that the weapon can be launched directly from the ground, that the tracking flare and battery are housed in a fairing above the body and that the boost motor is a separate charge clipped on underneath, with a nozzle canted downwards through 20°.

All that the operator needs is a simple control unit, weighing 5lb, containing coaxial cable sockets, a missile-selector dial, launch button and joystick. The tracking flare is red, and a telescopic sight can be used at ranges greater than about 1,000yd. The West Germany Army is already introducing the 810 as a standard weapon. A major commercial success was achieved when the American electronics firm of Daystrom Inc purchased manufacturing and sales rights for North America, and sold 100 German-made missiles for evaluation by the 1st Marine Division. It seems likely that the USMC will adopt the weapon.

Entac

Light wire-guided missile

FRENCH ARMY

DEVELOPED in competition with Nord's SS.10 by the Government Direction des Etudes et Fabrications d'Armément, Entac (Engin Tactique Anti-chars) appears to be slightly less refined than the privately produced missile but should be somewhat cheaper. In its transport container it forms a 53lb package which can be carried by an infantryman, although it is usual to deploy the missile on vehicles. A common arrangement appears to be for a jeep to carry eight rounds and to tow a trailer carrying three, both sets of missiles being mounted in batteries pivoted on hinges for elevation. A possible disadvantage of the system is that a crew of two is needed to operate it: a command-post supervisor and an optical tracker.

Malkara

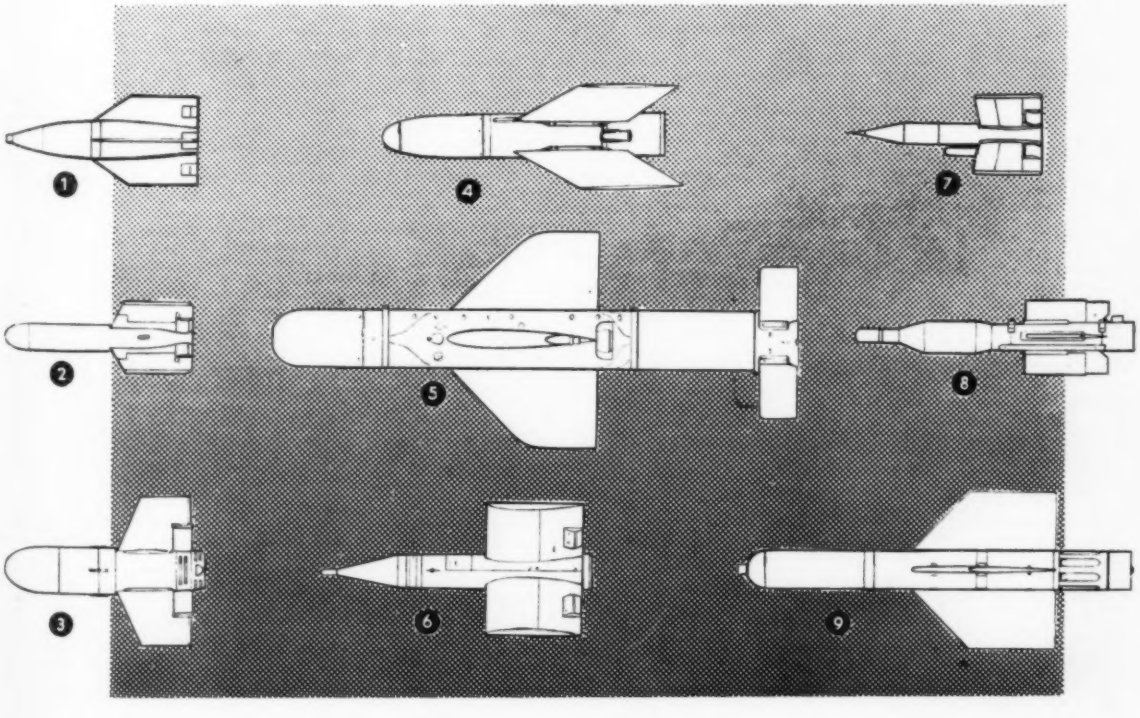
Heavy missile for deployment from vehicles

BRITISH ARMY

FOR many months it has been the avowed belief of the British War Office that the small infantry-borne missile cannot carry a warhead of the killing power required for modern tanks. Arguments about hollow charges and squash-type heads have raged loud and long, and the decision to conduct official assessment trials with Vigilant (*q.v.*) suggests that the official view may not long prevail; but while it held undisputed sway Fairey Aviation were given a contract to develop a heavy missile known as Orange William, and in August 1959 the Australian Malkara was bought for assessment trials. Eventually, the Fairey missile was cancelled and some 400 Malkara Mk 1 missiles were bought as an initial inventory quantity at a cost of about £1m. Malkara is to become the standard guided weapon of the Royal Armoured Corps and is to go into service next year. It can be deployed on any armoured vehicle, but will be particularly associated with a special air-portable scout car.

Details of the weapon, and of its history of development between the RAE and the Australian Government Aircraft Factories, were contained in our 1959 review. After departing from its overhead zero-length launcher, Malkara is guided by twin trailing wires from a control unit which not only provides correctly shaped signals in response to joystick demands but also incorporates checking and monitoring circuits. The circular-section rear body houses the blast tube from the boost/sustainer motor and carries four fixed fins indexed at 45° to the moving wings around the square-section centrebody. Tracking flares are mounted on the wingtips, and it is worth noting that at a demonstration near Lulworth in June a direct hit was achieved at a range of over a mile. Fairey Engineering has the sales agency for all countries outside the US, and has also been appointed the Australian Department of Supply's delegated authority to assist in the introduction of Malkara to operational service and to design and produce modifications.

ANTI-TANK MISSILES: 1, Entac; 2, Bantam; 3, Nord SS.10; 4, Nord SS.11; 5, Malkara Mk 1; 6, Mosquito; 7, Bölkow Bo 810; 8, V.897 Vigilant; 9, Pye PV. The tinted background panel represents a width of 12ft



Representative of the anti-armour systems of many nations is Switzerland's Puch-Haflinger vehicle carrying a quintet of Mosquitos

Mosquito

Wire-guided missile for infantry.

SWISS ARMY AND "OTHER CUSTOMERS"

DURING the past six years Contraves AG at Zurich and the Oerlikon Machine Tool Works, Bührle & Co, have developed this essentially simple wire-guided weapon for operation by a single infantryman. Reinforced plastics and fully transistorized guidance contribute to the light weight of the missile, and for transport two Mosquitos, with wings unclipped, are carried in a rigid box on the operator's back, the control box being slung round his neck. The missile is launched directly from the ground, the forebody being supported by an adjustable rod.

Mosquito is roll-stabilized by a powder gyro and steered by vibrating spoilers. An unusual feature is that the arming of the warhead is delayed until near to the target; the fuze of the hollow charge is armed by a signal resulting from a pre-set clockwork mechanism or by a deliberate action by the operator, transmitted through an *ad hoc* wire. A complete training simulator has been developed, together with a parachute recovery system for inert missiles. The Swiss Army deploy the Mosquito in rows of five carried on the Puch-Haflinger cross-country vehicle, and Contraves state that the missile is "in production for several customers."

Nord SS.10

Short-range, wire-guided missile

FRENCH ARMY *and armed forces of approximately 12 other nations*

DEVELOPMENT of this very effective little weapon was completed in 1953, and pilot production started at Chatillon shortly thereafter. To undertake inventory production Nord decided in 1957 to build an *ad hoc* plant at Bourges, and the first SS.10 left there in August 1958. More than 35,000 have since been delivered (out of Nord's total production of slightly more than 50,000 missiles), and 26,000 remain on order. With the standard 11lb warhead, which can penetrate up to 16in of armour, the SS.10 (Nord 5203) is priced at approximately £340, and the associated field equipment costs a further £1,750. A full description was published in our issue of February 7, 1958.

Nord SS.11

Short-range, wire-guided missile

FRENCH ARMY, NAVY AND AIR FORCE, US ARMY, WEST GERMAN ARMY *and several other nations (including a large evaluation order from Britain, chiefly for investigation of the air-to-ground role)*

PRODUCED by Nord-Aviation as the Type 5210, the familiar SS.11 is being manufactured at the rate of about 1,800 per month and has been in operational service since 1956. Compared with the SS.10 it is much heavier, and has approximately twice the weight, speed and range. A major difference is that the steering signals are used to energize solenoids at the extreme rear of the body to bias the vibration of four pivoted spoilers which intermittently interrupt the jet from the sustainer motor in order to provide an off-centre resultant thrust on the missile. Standard heads include the 125AC (17.6lb, including about 3.3lb of explosive, penetrating over 23.6in. of 51 tons/sq in armour impacting normally), the 140AP anti-personnel charge and the 140CCN for Naval use, which, while having a hollow annular charge, sacrifices penetration for greater destructive power.

SS.11 can be launched from a zero-length support strut on the ground, from vehicles or from aircraft. Its weapon system includes optical sighting equipment, a T9C signal generator, "joystick" control and box, fire-control checking box, selection unit, control box, communications telephones and the appropriate lengths of cable, and Nord have also developed complete simulation equipment. Earlier this year Nord announced the successful outcome of their efforts to make the weapon system usable by infantry. By the widespread introduction of transistors the fire-control equipment has been miniaturized and weighs only 11.5lb. Known as the Waist-Belt Fire Control, it comprises T.10 generator, battery, joystick and control unit, all mounted on a belt worn round the operator. Three men each carry one missile less head, and a fourth carries the three warheads. An infra-red guidance system is another line of development. Yet another version in service is a marine pattern, with measures taken to reduce loss of signal between the wires after they touch the sea.

One of the largest SS.11 contracts was an order placed last May by the Federal German Army worth over 10°F. It was announced in July that Nord and GE have signed an agreement giving the US company manufacturing rights which would be taken up if SS.11 were purchased in inventory quantity by the US Army. Already many hundreds of rounds have been fired by the US Army at Aberdeen proving ground, and the missile appears to stand a good chance of becoming standard equipment with that service. A full description appeared in our issue of November 14, 1958.

Pye PV

Medium-weight missile for deployment from vehicles or by infantry

PRIVATE VENTURE

DURING the past five years Pye Ltd, the renowned British electronics firm, have been financing the development of what they consider to be the optimum wire-guidance system. The work started with a painstaking investigation with many human operators to determine control problems, and the result was a combination of velocity and acceleration controls coupled with a signal-shaping unit. This was then used as the basis for a flyable system of hardware, including a unique jet-deflection control system in which the jet (but not the missile) is roll-stabilized with respect to earth axes.

Airframe features include a light-alloy tubular body and fixed wings of wrapped metal sheet over a honeycomb core. Pye designed the boost/sustainer motor and farmed production out to Bristol-Aerojet. Originally the wire reel was housed on a wing tip but it is now inside the body, the wire emerging from an orifice between one pair of wings. Pye are at present proving the jet control system, using a Ministry of Aviation range, and they recently exhibited a trio of PVs mounted on the AS.243 combat vehicle by the Belgian FN company.

Vigilant

Minimum-size weapon for infantry

BRITISH ARMY

A HISTORY and description of the Vickers-Armstrongs (Aircraft) V.891 development missile was contained in our issue of May 22 1959. At that time the company had been engaged in the project for two years, and (apart from the fact that the boost/sustainer motor had been developed for them by ICI) had borne the entire cost themselves. On August 25 last their perseverance was rewarded by an order for a substantial number of missiles for assessment trials by the British Army. These trials are scheduled to take place early next year.

From the outset Vickers chose a velocity-type control, the advantages of which over the competing acceleration control were outlined in our June 17 issue. In particular, it is now generally accepted that velocity control is easier to learn, skill is retained by an operator for much longer periods, and missile performance can be increased with fewer difficulties. Vigilant flies relatively fast for a wire-guided weapon and its manœuvrability is exceptional, turns at 4g and angles of attack of 30° being commonplace. Much of its structure is of reinforced plastics. Steering is effected by simple controls hinged to the trailing edges of the low-aspect-ratio wings, the actuators being pressurized by cordite gas. Cordite also serves the gyro, and the a.p.u. is driven by a turbine fed with gas bled from the propulsion tube. Guidance electronics are printed and transistorized strips screwed to the outside of the motor case. The operational V.897 can carry a range of warheads, weighing between 5lb and 12lb; the drawing shows a large head with a diameter of 5.16in and a 6.9in contact probe.

Some of the results obtained at Larkhill were commented upon in our September 2 issue. It was found possible to achieve 50 per cent strikes at 180yd, believed to be closer than anything any other missile can attempt. Trained operators can consistently hold the Vigilant within 18in of a fixed sight-line over ranges from about 250 out to more than 1,000yd. The addition of an autopilot automatically corrects any disturbance to the desired trajectory, and makes the weapon unusually steady in flight. Infantry normally carry a single round, in a rigid box with sight/controller and cable drum for remote operation, at a total weight of 45lb. Missiles can be fired within a few seconds of opening the box. Current price per round is about £500, but this should be reduced to something like £300 in bulk production. This is still relatively expensive, but Vickers claim that total weapon-system costs are very competitive. The Army consider five hours on the simulator and between two and five live firings to be adequate to train an operator, and that only two or three firings per year will keep him at the required standard.

ANTI-TANK MISSILES

	Launch wt (lb)	Warhead (lb)	Length (in)	Body D (in)	Span (in)	Range limits (ft)	Speed (m.p.h.)
Bantam	13.2	3.1	30	3.9	15.8	1,000-6,500	190
Cobra	20.9	5.5	42	3.9	19	1,640-5,250	190
Entac	26.5	—	32.6	—	15	-5,800	190
Malkara	206	60	76	8	31	500-6,000+	400
Mosquito	25	7.5	41.3	4.7	23.6	1,500-5,500	190
Nord SS.10	33	11	33.9	6.5	29.5	990-5,250	180
Nord SS.11	64	17.5	46	6.5	19.7	1,650-11,500	425
Pye PV	80	30	60	6	24	—	—
Vigilant	31	12	42	4.5	11	500-4,500	340

A S W

Representing an intermediate stage between conventional depth charges and the long-range ASW systems of the future, Asroc is now in service with the US Navy. Here a missile is fired from the cruiser "Norfolk"

Alfa

Surface-to-underwater system

US NAVY

ORIGINALLY known as Weapon Able, Alfa is an unguided rocket-propelled warhead launched from a tube positioned in azimuth and elevation by an associated fire control. The turret can point in almost any direction, the range of the missile obviates the need for the ship to approach the target, and the warhead sinks relatively rapidly. Alfa became operational in 1952.

Asroc

Surface-to-underwater system

US NAVY

ALTHOUGH it involves no "state of the art" advances as does Subroc, the US Navy's Asroc (anti-submarine rocket) system is much more effective than the defunct Rat (1958 review) which it replaces. The basic vehicle containing the warhead is a Mk 44 electrically propelled and acoustic-homing torpedo (or, rarely, a depth charge). To the rear of the torpedo is attached a tandem solid boost unit with a thrust of 11,000lb. Position of the target, determined by the ship's SQS-23 sonar system, is automatically translated by computer into launcher azimuth and elevation.

Range is determined by timing the cutoff of propulsion and ejecting the payload from the motor. Flight through the air may start at any angle up to at least 50°, and is purely ballistic. Entry to the water is cushioned by a 6ft parachute, and the torpedo thereafter runs home conventionally. It is claimed that the close integration between all parts of the system enable a target to be engaged only a few seconds after detection. Two destroyer leaders are nearing operational status with launchers carrying eight Asrocs. It is planned to put the missile aboard 150 ships, some of which will have the ability to reload their launchers. Prime contractor is Minneapolis-Honeywell.

Astor

Rocket-boosted torpedo

US NAVY

UNDER development by Westinghouse, this torpedo is rocket boosted and electrically propelled and has a guidance system which is unofficially reported to involve trailing wires. Either a conventional or nuclear warhead can be carried, and the system differs from most ASW weapons in that the warhead is steered all the way to the target. Astor is scheduled to be deployed with fleet submarines next year.

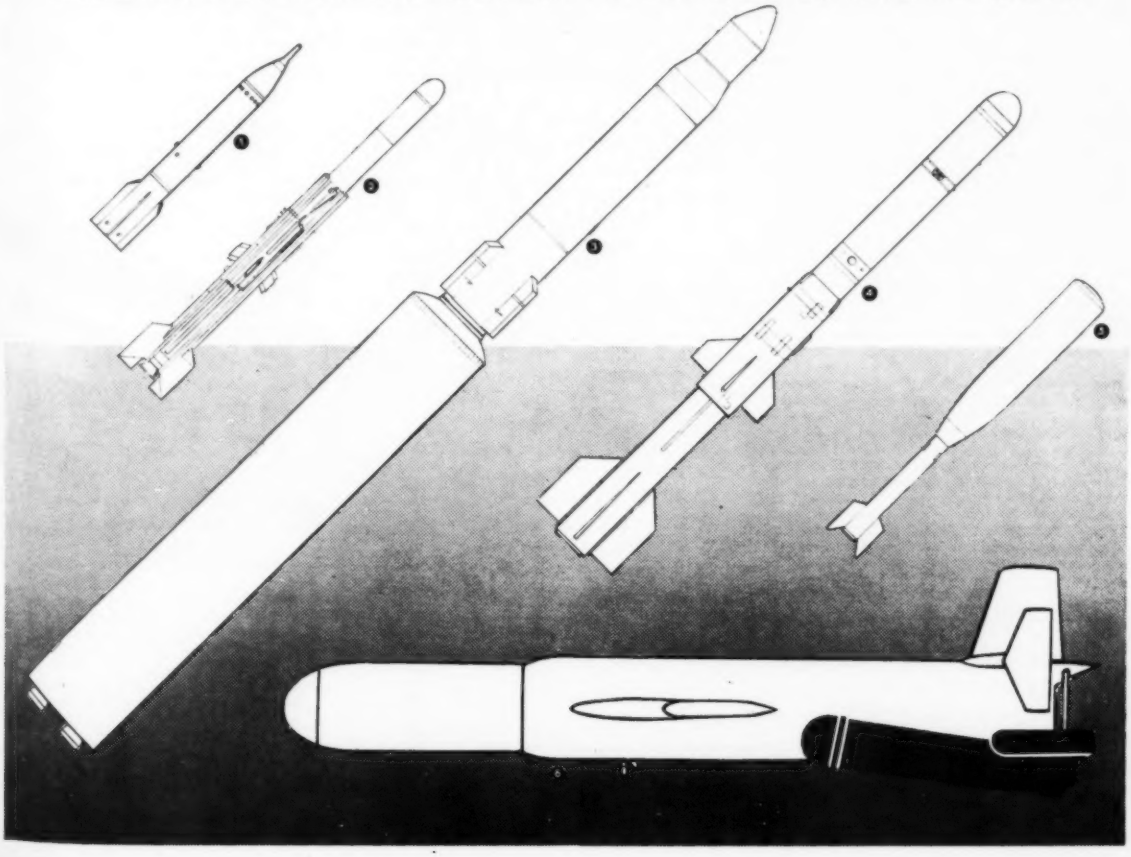
Malafon

Surface-to-underwater system

FRENCH NAVY

THIS is the French bite at the ASW cherry—one of the biggest problems currently facing the NATO nations. It is a straightforward bite, and is now within a few weeks of service. The warhead is contained in a 21in acoustic-

ASW MISSILES: 1, Terne; 2, Rat; 3, Subroc; 4, Asroc; 5, Alfa; 6, Malafon. The tinted background panel represents a height of 12ft



homing torpedo weighing 1,157lb. This is carried on the front of a miniature aeroplane devoid of an engine but launched from a rotating ramp at an elevation of 20° by a boost package containing twin solid motors. Malafon is launched automatically when a submarine has been picked up and fixed in position by the ship's sonar and computer system. After boost jettison, at a speed of perhaps 400 m.p.h., the controls of the airframe are released and the missile manœuvred by twist-and-steer while maintaining a constant altitude (usually of about 330ft) above the sea. The radio-command system brings the missile into the area of the target until, at the most opportune point, its flight is arrested by a parachute streamed from the tail. The torpedo then drops into the water and homes on the target.

In the development of the system the French Navy were assisted by an industry team led by the Soc Latécoère, of Toulouse. First ship scheduled to receive the weapon is the 3,750 ton *La Galissonnière*, an escort vessel nearing completion at Lorient. Many development rounds have been fired from land (Ile du Levant) and afloat (*Ile d'Oléron*), and production is in hand.

Rat

Surface-to-underwater system

US NAVY

ALTHOUGH cancelled in January 1959, this rocket-assisted torpedo system has been included in the scale drawings for comparison with its successors. It was described in the 1958 review.

Subroc

Underwater-to-underwater or surface-to-underwater system

US NAVY

UNDER an initial prime R & D contract worth $65m, Goodyear Aircraft have since June 1958 been engaged in the development of Subroc (submarine rocket). It is said to "detect a submarine at long range, compute its course and speed, and fire the missile. The missile is propelled through the air by a rocket which drops away and the warhead continues on to the target. The weapon can destroy enemy targets in an area of many square miles around the launching submarine." Although the final delivery vehicle is not large, the overall weapon system poses problems of immense magnitude. When these have all been solved it will be possible to detect and destroy submarines at several times the maximum range currently obtainable.

Exactly how a submarine can be detected at a range of from 25 to 50 miles cannot yet be divulged. When the co-ordinates of the target are known, the Subroc system prepares to launch the missile, the subcontractors for fire control and guidance being Librascope and Kearfott, respectively. The vehicle itself is virtually a supersonic rocket-propelled ballistic missile, provided with fin-like axial protruberances near the tail which, possibly in partnership with jetevators on the booster, may control the trajectory. The vehicle is launched from a torpedo tube either above or below the water surface. It accelerates through the atmosphere under the thrust of a large Thiokol solid motor with four nozzles provided with jet deflection. This tandem booster gives the missile range, altitude and speed far surpassing that of any previous ASW system. After separation, the warhead, of either the nuclear or conventional type, completes its ballistic trajectory and impacts in the target area. With a nuclear warhead the lethal radius is greater than the distance which a submarine can run during the time between booster cutoff (and consequent cessation of guidance) and detonation.

A year ago Goodyear announced details of the Subroc telemetering system, which has to gather data on shock and vibration, acceleration, flight characteristics and environmental conditions. The airborne telemetry package is roughly 10in diameter and 24in long, and weighs 75lb. The complete Subroc system will initially be installed in a class of nuclear attack submarines. The first of these ships, USS *Thresher*, will commission next year.

Terne

Rocket-propelled depth charge

ROYAL NORWEGIAN NAVY; being purchased by US NAVY

DURING the past ten years the Norwegian Defence Research Establishment has been investigating an improved ASW system forming a logical extension of existing Asdic/Sonar systems coupled to projectors for unguided depth bombs. In particular, the Norwegians aimed at producing a system which could readily be installed aboard small escort vessels, and to this end the weight, bulk, launch thrust transmitted to the deck, electrical consumption and general level of sophistication and cost had to be made compatible with such applications.

Installed in the ship are a search sonar, operating on a frequency of 11kc/s and able to detect submarines or torpedoes from 3,000 to 5,000yd distant, and an attack sonar operating on 30kc/s and with split beams to determine the target's vertical and horizontal location with an accuracy within one per cent out to about 3,500yd. Data from these two sets are corrected and refined by four human operators before transmission to the fire-control computer. Inputs to the latter include the speed, course, roll and pitch of the ship, wind velocity and the temperature of the solid propellant in the Terne missiles. The computer determines future positions of the submarine and converts these into desired azimuth and elevation for the missile launcher.

The latter weighs 3,400lb and accommodates six Ternes at a time. It is stabilized within ±20° in roll and ±5° in pitch and can be reloaded in about 45sec. Normally, all six missiles in the launcher would be fired in salvo, their actual departure being sequenced at intervals of 0.75sec in order to minimize reaction on the deck. Since the Terne has no airborne guidance system it is an essentially simple and cheap device, and more than one-third of its launching weight is warhead. Although the weapon could undoubtedly carry a sub-nominal nuclear charge, all Ternes so far built have carried a 90lb conventional warhead detonated by an acoustic proximity fuse (or, for use against targets very near the surface, by a direct timing mechanism.

Development of the Terne system was handled jointly by the Defence Research Establishment and the Kongsberg Vapenfabrikk, with technical and financial assistance under the MWDP. Extensive trials aboard an escort vessel of the Royal Norwegian Navy have proved satisfactory, and the complete weapon system, which weighs about 23,000lb, is now in full production at Kongsberg for a number of NATO Navies. Four months ago it was announced by the US Navy that American Bosch Arma had been awarded a $1.5m contract to convert the system to meet USN specifications, and it is likely to be adopted by that service as standard equipment.

Most advanced ASW missile currently in a late stage of development is Goodyear's Subroc. This is an artist's impression of the climb under rocket power before booster burnout

Forming a marked contrast with Subroc is the French Navy's Malafon, developed principally by Latécoère, a famous aircraft company. It is fully guided, but has no internal engine

ASW SYSTEMS

	Mission	Propulsion sequence	Range (yd)	Launch wt (lb)	Length (in)	Body D (in)	Warhead
Alfa	S-A-U	Internal rocket	900	500	102	12.75	h.e. 500lb
Asroc	S-A-U	Rocket, then torpedo	16,000	2,500	180	30	N (10kT?)
Astor	U-A-U	Rocket-boosted torpedo	2,000	2,300?	220	21	221lb
Malafon	S-A-U	Rocket, glider, torpedo	19,000	—	—	—	N (20kT?)
Subroc	U-A-U	Rocket, then ballistic	80,000?	7,000?	—	30	90lb
Terne	S-A-U	Internal rocket	2,500	265	77.5	7.9	